

# **Essays in Monetary and Macprudential Policies**

By

**Indrani Manna**

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Professor William Barnett, Chairperson

---

Professor Zongwu Cai

Committee members

---

Professor John Keating

---

Professor Shu Wu

---

Professor Zsolt Talata

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The Dissertation Committee for Indrani Manna certifies  
that this is the approved version of the following dissertation :

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Professor William Barnett, Chairperson

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## **Abstract**

This dissertation consists of three chapters. The first chapter - “Modelling Weights and Dependence Parameters in Mixed Copulas using Penalized Likelihood - Various Applications”, relates to modelling of the weights and dependence parameters of copulas and using data driven copula selection methods to select the correct copula structure underlying the data. The first part of the paper uses a parametric weight specification to model the dependence parameters, as a regression equation of exogenous variables. The model is simulated using a modified EM algorithm and the non-linear dependence structure is studied in a relatively new area namely the offshore exchange markets in India. In the second application with parametric weights, the dependence structure in US housing markets is studied. Results show that while the Gaussian copula is enough to characterize the dependence structure in offshore markets in India, housing markets in New York and Kansas exhibit negative dependence. The second part of the paper designates weights as non-parametric (unknown) functions of structural variables leading to functional index coefficient model structure coupled with selection of mixed copula. The model has been simulated and applied to measure the dependence structure of money markets in Denmark which have recently taken to negative interest rates. Results show that the shares of normal and frank copulas have been steadily declining while the share of copulas with extreme dependence has been rising with a prominent rise of clayton copula in the bivariate distribution of short and long run interest rates post financial crisis.

The second chapter of the dissertation - “Asset Price Volatility and Optimal Policy

Mix in Overlapping Generations Model”, revisits a perennially unresolved issue – the question of central bank intervention in managing asset bubbles through the Taylor rule or through (calibrated or un-calibrated) macroprudential policy intervention in credit disbursement. The chapter lays down the theoretical foundations of macroprudential policies like capital adequacy by extending Gali (2014) overlapping generations economy with credit frictions. While the results of the model with financial frictions vindicate Gali (2014) that a leaning against the wind monetary policy generates a larger volatility in the bubble than a policy of benign neglect, the paper finds that minimisation of bubble volatility requires an active macro-prudential policy. It is also observed that stronger interest rate response of monetary policy to the bubble necessitates a stronger macroprudential response possibly to absorb the excess volatility generated by the monetary policy. However, the paper also finds that tightening macroprudential policy parameter beyond a threshold value may encourage banks to take more risks and increase credit supply, aggravating the bubble in the process. With respect to macroprudential policy, there is no conflict between stabilization of current aggregate demand and stabilization of future aggregate demand and both call for a strong macroprudential response, at least until the macroprudential parameter attains the threshold value, although the conflict between the two objectives persists with respect to monetary policy as in Gali (2014).

The second paper has been empirically verified through a vector autoregression with sign restrictions approach of (i) Mountford and Uhlig (2005) penalty function approach (PFA); and (ii) Andrew Binning’s underidentified SVAR approach. Using US data, this paper finds that provisioning shock in general and dynamic loan loss provisioning shock, in particular reduces stock prices and dampens output growth as opposed to monetary policy. This result is substantiated both under recursive SVAR specifications as well as sign restrictions imposed according to Mountford and Uhlig

(2005) specification. However, by combining sign and zero restrictions in an under-identified SVAR model proposed by Binning(2013),the paper finds that stock prices decline when variables are assumed to be responding to provisions shock only in the long run and the provisions shock is exactly identified. However, when sign restrictions are imposed on inflation, impact response of stock price to provisions shock as well as monetary policy shock is ambiguous. However, stock prices decline during the second quarter in response to a provisions shock.

Chapter 3 - “Financial Inclusion, Financial Stability and Credit Cycles in EMEs” examines the role of monetary and macroprudential policy in enhancing financial stability in the backdrop of bank-based financial inclusion in emerging market economies like India. A new Keynesian DSGE model of heterogeneous households characterised by various financial frictions typical of an economy adopting bank-based financial inclusion measures is constructed. Results from the DSGE model show that increased financial inclusion may accelerate credit flow to all sectors and raise output if the banking correspondent agents serve as business facilitators involved through the life cycle of the loan and not merely intermediaries involved in cash in and cash out type of transactions. The non-performing asset to gross loan ratio declines indicating the model promotes financial stability. The result confirms how appropriate involvement of BCAs can attenuate the problem of adverse selection for the bank raising overall credit supply in the economy. With respect to standard shocks, financial inclusion seems to delay the impact of monetary tightening, while contractionary macroprudential shocks have the desired impact but lead to a net transfer of wealth from impatient borrowers to entrepreneurs. Using data from 29 countries spanning Asia, Africa, Latin America and peripheral Europe and twin methods - (i) cointegration and VECM techniques and (ii) VAR with long run restrictions using instrumental variables, the paper also investigated the long run relationship between financial inclusion and

financial and banking stability and the significance of permanent shocks to financial inclusion. The cointegration analysis confirms the presence of a common stochastic trend running through credit to domestic sectors, non-performing loans (NPLs) as a proportion of total loans and bank regulatory provisions as a per centage of total assets in 24 of the 29 countries surveyed. In 14 of the 24 countries, there is clear evidence of a permanent decline in NPLs following an inclusion shock. All sample countries that implement bank based financial inclusion exhibit this trend with the exception of Turkey and Peru. The VAR analysis with long run restrictions does not confirm a statistically significant reduction of NPLs following a permanent shock to financial inclusion. However, crucial evidence is found confirming the reduction in NPLs in the long run following a positive productivity shock and a rise in credit following a permanent financial inclusion shock.

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# Chapter 1

## **Modelling Weights and Dependence Parameters in Mixed Copulas using Penalized Likelihood - Various Applications**

### **1.1 Introduction**

Copula applications are well documented in the financial literature. Deviation from normality is a common phenomenon in financial time series and hence Pearson's correlation and concepts based on linearity may not be able to completely characterize the dependence in non elliptical distributions. Embrechts et al (2002) illustrates that a dependence measure like linear correlation may not be a perfect measure of dependence because it fulfils only two desired properties of an ideal dependence measure viz., symmetry and normalisation but falls short of other properties such as comonotonic and countermonotonic.

However, a major question that confronts researchers in most copula applications is how to choose the correct functional form of copula. In the extant literature, the choice of copula functional form is decided based on certain goodness of fit tests such as Kolmogorov Smirnov and Anderson and Darling type tests developed by Koe, Koedijk and Verbeek (2007), kernel-based tests of Scalliet(2007) and omnibus tests of Genest, Remillard and Beaudoin (2009). However, this literature could not resolve the issues as to which copula model should be used if the null hypothesis is rejected in these tests (Cai and Wang (2014)). In contrast, Cai and Wang (2014) provide a theoretical foundation for a data driven mixed copula selection method using penalized likelihood plus a shrinkage operator in the spirit of LASSO. Empirically a mixed copula can provide flexibil-

ity in modelling and describing dependence structure. Further, Cai and Wang's approach enables simultaneous copula selection and estimation of dependence parameters.

It is also realized that in their present form, copulas have limited use in economic policy inference because of interpretability issues with the dependence parameter. Copula dependence is not as intuitive as the linear correlation coefficient limiting their use in economic policy inference. In this paper, constructing on the method proposed by Cai and Wang(2014), I model the weights and dependence parameter of copulas, (a) first as a parametric regression function of various macroeconomic variables and (b) as an unknown non-parametric function of structural variables using functional index coefficient models. The coefficients of the regression model will be more easily and intuitively interpretable than the copula dependence parameter itself. Thus along with simultaneous copula selection and estimation, this model will also be easy with interpretation. This paper is not the first of its kind. Patton (2006) had earlier attempted to model the dependence parameter in gaussian copulas but he did not use selection approach and restricted his analysis to gaussian and joe-clayton copula. In terms of applications, I apply copulas to model the bivariate conditional joint distribution in three relatively new areas. We undertake detailed simulations of the two models in section. In section, we attempt several empirical applications. In the parametrics case, our first application is in onshore and non deliverable forward exchange rate market for Indian Rupee(INR) for pre and post crisis periods. Post global financial crisis and with increasing debates about currency internationalisation of EME currencies like the Chinese renminbi and Indian rupee,there is an increasing interest in developing country policy circles to enhance the use of the currency outside the economy. But it is equally concerning, that the spotlight on offshore forex markets has tightened in almost all developing economies with capital controls because of rapid volatility movements in the spot exchange rate markets, particularly during periods of depreciation. Of late, there is news of volatility spillovers from offshore market to the spot market motivating us to study the non-linear dependence structure in these markets. My second application with parametric weights is based on US housing market inspired by the work of Fairchild, Ma and Wu (2014). In my third application with non-parametric weights, I examine the money market

integration in the Euro area, particularly in areas which have implemented negative interest rates in the last few years.

The paper is organised in the following order. Section II discusses some dependence concepts. Section III reviews the literature on copulas. Section IV elaborates on the theory behind selection of mixed copulas using penalized likelihood while Section V talks about various estimation procedures. Section VI details the simulations results while Section VII elaborates on the three empirical applications. Section VIII elaborates the estimation of the model with non-parametric weights.

## 1.2 Some Dependence Concepts

“A multivariate model should be analysed for the types of dependence structure that it covers as well as range of dependence. The dependence properties are important in order to know if a particular model might be suitable for a given application or a dataset” - (Joe,1997). The mathematical concept of dependence is much broader and more sophisticated than that considered in economic contexts. The dependence between two non-normal random variables cannot be summarized with general association measures like the Pearson’s linear correlation coefficient. An exhaustive summary of various dependence concepts used in literature is described in Joe (1997) and Nelson (2006). Below, I describe some directly relevant dependence concepts to facilitate the study.

### 1.2.1 Positive Quadrant Dependence

Definition: (Joe;1997): If  $X = (X_1, X_2)$  is a bivariate random vector with cumulative distribution function  $F$ , then  $F$  is positive quadrant dependent if

$$Pr(X_1 > a_1, X_2 > a_2) \geq Pr(X_1 > a_1)Pr(X_2 > a_2)$$

$$\forall a_1, a_2 \in R$$

, or,

$$Pr(X_1 \leq a_1, X_2 \leq a_2) \geq Pr(X_1 \leq a_1)Pr(X_2 \leq a_2)$$

In other words,  $X_1$  and  $X_2$  are more likely to be large or small together than  $X'_1$  and  $X'_2$  as compared with a vector of independent random variables with same corresponding univariate margins (Joe, 1997).

### 1.2.2 Stochastic Increasing Positive Dependence

If  $X = (X_1, X_2)$  is a bivariate random vector with cumulative distribution function  $F \in (F_1, F_2)$ , then the conditional distribution  $F_{2|1}$  is stochastically increasing if

$$Pr(X_1 > a_1 | X_2 = x_1) = 1 - F_{2|1}(x_1 | x_2) \uparrow x_1 \forall x_2$$

### 1.2.3 Right Tail Increasing and Left Tail Decreasing

Let  $X = (X_1, X_2)$  be a bivariate random vector with cdf  $F \in F(F_1, F_2)$ .  $X_2$  is right tail increasing in  $X_1$  if

$$Pr(X_2 > x_2 | X_1 > x_1) = \bar{F}(x_1, x_2) / \bar{F}_1(x_1) \uparrow x_1 \forall x_2$$

$X_2$  is left-tail decreasing in  $X_1$  if

$$Pr(X_2 \leq x_2 | X_1 \leq x_1) = F(x_1, x_2) / F_1(x_1) \downarrow x_1 \forall x_2$$

### 1.2.4 Associated Random Variables

Let  $X$  be a random  $p$ -vector.  $X$  is positively associated if the inequality

$$E[g_1(X)g_2(X)] \geq E[g_1(X)]E[g_2(X)]$$

holds for all real valued functions  $g_1$  and  $g_2$  which are increasing in each component. A positive dependence condition for  $X$  implies that two increasing functions of  $X$  have positive covariance whenever the covariance exists.

## 1.3 Definition and Related Literature

Many papers and text books have described copula as a link function that 'joins or couples multivariate distribution functions to their one dimensional marginal distribution functions' (Nelson(2006)). But Nelson(2006) provides a more in-depth definition of copulas.

Definition1: (Adapted from Nelson(2006)) Suppose  $X$  and  $Y$  is a pair of random variables with distribution function  $F(x) = P(X \leq x)$  and  $G(y) = P(Y \leq y)$  and a joint distribution function  $H(x,y) = P(X \leq x, Y \leq y)$ . So each pair of real numbers  $(x,y)$  leads to a point  $(F(x),G(y))$  in the unit square  $[0,1] \times [0,1]$  and this ordered pair corresponds to a number  $H(x,y)$  in  $[0,1]$ . Thus a copula is a correspondence which assigns a value of joint distribution function to each ordered pair of values of individual distribution function.

Thus bivariate/multivariate distribution modelling with copulas involves two key stages: Identifying the marginal distribution of the univariate series and then identifying the copula. Copula literature is replete with parametric and non parametric methods to model marginal distributions and copulas. A key issue in applying copulas to practical applications is to choose the correct parametric copula because we have no prior knowledge of the distribution from which the data is drawn. Further different copula families contribute differently towards dependence. Thus while the gaussian copula is symmetric with no tail dependence, clayton and gumbel copula have nega-

tive and positive dependence, respectively. For a proper evaluation of the multivariate density, we need to give due weights to different dependence structures, probably data driven weights. Hence it is legitimate to consider a mixed copula which warrants different weights to different copulas. A key method used in selecting the component copulas in mixed copula analysis is the penalized log likelihood method. In an empirical analysis, Hu(2006) considered a mixed copula by deleting the component if corresponding weight is lower than 0.1 or if the corresponding dependence measure is close to independence. Cai and Wang(2014) were the first to develop a data driven copula selection method via penalized likelihood. Cai and Wang (2014) were of the view that best mixed copula can be selected by choosing the one with highest likelihood. The idea is to fit a copula and drop all the component copulas with very small weights which indicate very small contribution to dependence.

## 1.4 Theory

Let  $(X_t)_{t=1}^T$  be independent p-dimensional vectors of random variables with  $X_t = (X_{t1}, X_{t2}, \dots, X_{tp})^T$ . Let  $F(x)$  and  $f(x)$  be the distribution and joint density of  $X$ , respectively. Also let  $f_j$  and  $F_j(X_j)$  be the marginal density and distribution of  $X_j$ , respectively for  $1 \leq j \leq p$ . Cai and Wang (2014) define a mixed copula as a linear combination of several copula families represented as

$$F(x; \phi) = C(u; \theta) = \sum_{k=1}^s \lambda_k C_k(u; \theta_k) = \sum_{k=1}^s \lambda_k C_k(F_1(x_1; \alpha_1), \dots, F_p(x_p; \alpha_p); \theta_k)$$

where  $C_1(\cdot) \dots C_s(\cdot)$  is a set of basis copulas which is a sequence of known parametric copulas with unknown dependence parameters  $\theta_k$ .  $[\lambda_k]_{k=1}^s$  are the weights satisfying  $0 \leq \lambda_k \leq 1$  and  $\sum_{k=1}^s \lambda_k = 1$  also called a shape parameters. And  $\alpha = (\alpha_1, \alpha_2, \dots, \alpha_p)$  is the vector of marginal parameters for marginal distributions. Let  $\phi = (\alpha^T, \lambda^T, \theta^T)^T$  be the vector of all parameters involved.

The joint density function then is given as

$$f(x; \phi) = \prod_{j=1}^p f_j(x_j; \alpha_j) \sum_{k=1}^s \lambda_k c_k(F_1(x_1; \alpha_1), \dots, F_p(x_p; \alpha_p); \theta_k)$$

where  $c_k(u; \theta_k) = \frac{d^p C_k(u; \theta_k)}{du}$  is the mixed partial derivative of the copula  $C(\cdot)$  and we assume these copula densities exist as in Cai and Wang (2014). With iid data, the penalized log likelihood takes the following form

$$Q(\phi) = \sum_{n=1}^N \sum_{j=1}^p \ln(f_j(X_{jn}; \alpha_j)) + \sum_{n=1}^N \ln\left(\sum_{k=1}^s \lambda_k c_k(F_1(X_{1n}; \alpha_1), \dots, F_p(X_{pn}; \alpha_p); \theta_k)\right) - N \sum_{k=1}^s p(\lambda_k) + \delta\left(\sum_{k=1}^s \lambda_k - 1\right) \quad (1.1)$$

I propose to expand this concept by modelling the weights and dependence parameters of the copulas so as to provide more economic content to the whole idea. I concentrate on the bivariate copulas because it is analytically tractable and graphically explainable.

### 1.4.1 Modelling Copula Dependence Parameters as Regression Equation:

To begin with, let's start by expressing the dependence parameters in the regression framework. I regress the dependence parameters on a  $k$ -dimensional vector

$Z_T = (Z_1, Z_2, \dots, Z_k)$  of macro-variables or simply the trend. The dependence parameters are modelled as a function of these exogenous variables

$$\theta_{i,t} = \theta(\beta' Z^T)$$

where  $\theta$  is a known link function particular to the copula in question to ensure that the copula parameter and weights stays in the required range.

Thus we estimate

$$C(u; \theta) = \sum_{k=1}^s \lambda_k C_k(F_1(x_1; \alpha_1), F_2(x_2; \alpha_2); \theta_k(\beta'Z^T))$$

using penalized likelihood.

### 1.4.2 Modelling Weights and Dependence

Like the dependence parameter, the weights could also be subject to exogenous shocks. For example, it is interesting to see how the weights on copulas of term structure of interest rates vary with exogenous monetary policy shock. In other words,

$$\lambda_{k,t} = \lambda(\beta'Z^T)$$

where  $k \in [Ga, Cl, Fr, Gu]$ , where Ga refers to Gaussian copula, Cl refers to Clayton copula, Fr refers to Frank copula and Gu refers to Gumbel copula.

Thus we can model dependence parameter and weights together to estimate the following

$$C(u; \theta) = \sum_{k=1}^s \lambda_k(\kappa'Z^T) C_k(F_1(x_1; \alpha_1), F_2(x_2; \alpha_2); \theta_k(\beta'Z^T))$$

We begin our analysis in an exploratory mode and start with generic penalty functions such as L2 regularization  $p(\lambda_k) = (\sum_{k=1}^s \lambda_k^2)^{1/2}$ . We then build on the structure emerging from the results with more sophisticated penalty functions such as smoothly clipped absolute deviation penalties (SCAD) as used in Cai and Wang (2014).

## 1.5 Estimation

The two established methods for estimation of copula models in the literature are the (i) Exact Maximum Likelihood Method and (ii) Inference of Margins Method (IFM). In the Exact Maximum Likelihood Method, marginal parameters and the copula parameters are estimated simultaneously through the maximisation of the log likelihood



$$l(\phi) = \sum_{t=1}^T \ln(c_k(F_1(x_1; \alpha_1), \dots, F_p(x_p; \alpha_p); \theta_k)) + \sum_{t=1}^T \sum_{j=1}^n \ln(f_j(x_{jt}))$$

where  $\phi$  is the set of all marginal and copula parameters. Under regularity conditions, the maximum likelihood estimator (MLE) exists and it is consistent and asymptotically efficient. Also it is asymptotically normal

$$\sqrt{T}(\hat{\phi} - \phi_0) \rightarrow N(0, \Gamma^{-1}(\phi_0))$$

where  $\Gamma(\phi_0)$  is the Fisher's Information matrix and  $\phi_0$  is the true value (Cherubini et al, 2004). On the other hand, the alternative method, IFM method, is based on the inference function theory as proposed by Joe and Xu (1996). In this method, instead of maximising the multivariate log-likelihood in all the parameters together, one can estimate different parameters of different marginal distributions of the multivariate distribution. The inference functions are score functions of likelihoods of marginal distributions. The first step involves estimation of the maximum likelihood estimate of the marginal parameters,  $\hat{\alpha}_j$  such that

$$\hat{\alpha}_j = \text{Argmax}_{\alpha_j} \sum_{t=1}^T \sum_{j=1}^n \ln(f_j(x_{jt}; \alpha_j))$$

and second step involves estimation of the copula parameter

$$\hat{\theta}_k = \text{Argmax}_{\theta_k} \sum_{t=1}^T \ln(c_k(F_1(x_1; \alpha_1), \dots, F_p(x_p; \alpha_p); \theta_k))$$

The IFM estimator also satisfies the property of asymptotic normality

$$\sqrt{T}(\hat{\phi}_{IFM} - \phi_0) \rightarrow N(0, G^{-1}(\phi_0))$$

where  $G(\theta_0)$  is the Godambe Information matrix.

Cai and Wang (2014) use a full maximum likelihood approach to estimate the copula parameters in an iterative algorithm. This is a two step expectation-maximization algorithm where in

the E-step estimates the conditional probability of the observations coming from each component copula and the M-step estimates the dependence parameters. As in Cai and Wang (2014), we have the joint density function

$$F(x, \phi) = \lambda_{Ga} C_{Ga}(F_1, F_2; \theta_{Ga}) + \lambda_{Cl} C_{Cl}(F_1, F_2; \theta_{Cl}) + \lambda_F C_F(F_1, F_2; \theta_F) + \lambda_{Gu} C_{Gu}(F_1, F_2; \theta_{Gu}) \quad (1.2)$$

where  $C_{Cl} = [\max(u^{-\theta_{Cl}} + v^{-\theta_{Cl}} - 1, 0)]^{-1/\theta_{Cl}}$  is the CDF of the Clayton copula where  $\theta_{Cl} \in [1, \infty)/0$  is the dependence parameter.

$C_F = -\frac{1}{\theta_F} \ln(1 + \frac{(e^{-\theta_F u} - 1)(e^{-\theta_F v} - 1)}{e^{-\theta_F} - 1})$  is the CDF of the Frank parameter where  $\theta_F \in (-\infty, \infty)$  is the dependence parameter.

$C_{Gu} = \exp((-1) * [(-\ln(u))^{\theta_{Gu}} + (-\ln(v))^{\theta_{Gu}}])^{1/\theta_{Gu}}$  is the CDF of the Gumbel parameter where  $\theta_{Gu} \in [1, \infty)$

However, we add to Cai and Wang (2014) by modelling the weights and dependence parameters as a regression equation of (a) exogenous processes  $Z_t$  and (b) trend

$$\lambda_k = \lambda(\beta' Z^T)$$

$$\theta_k = \theta(\beta' Z^T)$$

where  $\lambda$  and  $\theta$  are known link functions particular to the copula in question to ensure that the copula parameter and weights stays in the required range. We choose the link functions keeping in mind the domains of the dependence parameter such that  $\theta_{Ga} = 1 - \exp(-\gamma * z + \varepsilon_1) / (1 + \exp(-\gamma * z + \varepsilon_1))$  remains in the domain  $(-1, 1)$  (Patton, 2006). Similarly, the dependence parameter for Clayton was  $(1 + \frac{\exp(\gamma * z + \varepsilon_2)}{1 + \exp(\gamma * z + \varepsilon_2)})$  so as to keep the parameter within the domain of  $[1, \infty)$  and the parameter for Frank copula was expressed as  $(\frac{1}{\exp(\theta * z + \varepsilon_3)} + \exp(\theta * z + \varepsilon_3))$

The estimation of the regression coefficients on the dependence parameter as well as the weights amounts to adding an additional block to the existing EM algorithm. The score function w.r.t regression coefficient on dependence parameter is non linear and hence coefficient is estimated by applying Newton Raphson methodology. It is easy to see that modelling the weights by using logit link functions does not alter the nature of the EM algorithm although the weights are now treated as functions. However, we still need to update the weights by estimating the regression coefficient. The coefficient is estimated through non linear least squares which is a consistent estimate.

## 1.6 Simulations

Simulations are designed as in Cai and Wang (2014). In the first set of simulations, only the dependence parameter is modelled and not the weights. Simulated examples are constructed consisting of single copulas as well as mixed copulas. As in Cai and Wang(2014), a data generating process where the bivariate joint distribution has a form of copula function and individual variables are normally distributed is used. The marginal distributions are distributed with marginal parameters  $(\mu_1, \sigma_1) = (1, 0.5)$  and  $(\mu_2, \sigma_2) = (0, 2)$ .

Each time data is generated from a single copula for three different sample sizes,  $N=400,700$  and 1000 which implies that weight corresponding to that particular copula is 1 and the weight corresponding to other copulas is zero. Then the penalized maximum likelihood estimates are computed. The simulation is run 500 times. The bias and mean squared error is reported in Table 1.1. It may be seen that the bias declines with the increase in sample size. All the estimates are close to arbitrarily given initial values.

Table 1.2 details the percentages of correctly selected copulas. It may be observed that there is 100 per cent chance to choose the correct single copula when the underlying copula in the population is either Frank, Clayton or Gumbel. However, we encounter a problem similar to Cai and

Table 1.1: **Biases and MSEs of Copula Weights Estimates from the Simulation Exercise**

		Clayton	Frank	Gaussian	Gumbel
N					
400	Bias	-0.0325	-0.092	-0.966	-0.487
	MSE	0.011	0.000	0.935	0.001
700	Bias	-0.0063	-0.00013	-0.927	-0.392
	MSE	0.000	0.000	0.859	0.0007
1000	Bias	-0.0052	-0.00011	-0.953	-0.269
	MSE	0.0000012	0.000	0.00000018	0.000

Wang (2014) but of a larger magnitude as to identification of gaussian copulas in the population. We find that the proposed method misidentifies gaussian copula as frank copula majority of the time. Although this may be attributed to the similar structure of the dependence of the two copulas, it remains a drawback of the method.

Table 1.3 provides the simulation results with respect to the SCAD penalty. The proposed method clearly identifies the copula when the underlying copula is either clayton or gumbel. The identification problem with Frank and Gaussian persists even with SCAD penalty. However, the problem seems to be declining with the sample size.

## 1.7 Empirical Application

### i) Housing Prices

Fairchild, Ma and Wu (2014) decomposed price-rent ratios of 23 major housing markets in the US into national and independent local factors using a dynamic factor model. The paper finds that a large fraction of housing market volatility is local and that the national factor has become more important than local factors in driving housing market volatility since 1999. If common under-

**Table 1.2: Percentage that the Corresponding Copula was selected Correctly (Incorrectly) in the Simulations**

	N	Clayton	Gaussian	Frank	Gumbel
Clayton	400	1.00	0.00	0.00	0.00
	700	1.00	0.00	0.00	0.00
	1000	1.00	0.00	0.00	0.00
Gaussian	400	0.00	(1.00)	0.00	0.00
	700	0.00	(1.00)	0.00	0.00
	1000	0.00	(1.00)	0.00	0.00
Frank	400	0.00	0.00	1.00	0.00
	700	0.00	0.00	1.00	0.00
	1000	0.00	0.00	1.00	0.00
Gumbel	400	0.00	0.00	0.00	1.00
	700	0.00	0.00	0.00	1.00
	1000	0.00	0.00	0.00	1.00

**Table 1.3: Biases and MSEs of Copula Weights Estimates from the Simulation Exercise (with SCAD penalty)**

		Clayton	Frank	Gaussian	Gumbel
N					
400	Bias	0.001	0.665	-0.897	0.001
	MSE	0.000	0.161	0.000	0.001
700	Bias	0.014	-0.482	-0.618	-0.000
	MSE	0.000	0.236	0.000	0.000
1000	Bias	0.001	0.093	-0.789	0.000
	MSE	0.000	0.034	0.000	0.000

Table 1.4: **Weights and Regression Coefficient Estimates in US Housing Markets**

	Clayton	Frank	Gaussian	Gumbel
Weights	0.84	0.181	0.0005	0
Coefficient on National Factor	2.16	0.5	-	0
Coefficient on Local Factors	0.31	0.5	-	0

lying factors is affecting the US housing market, it should be reflected in the correlation across these markets. This empirical example applies the above method to test how the copula dependence parameter relates to these unobserved factors underlying housing markets across time. So like Fairchild, Ma and Wu (2014), a dynamic factor model is used to segregate the various national and local factors that regulate the movement of housing prices in US first and then the copula dependence parameters are regressed on those factors through the proposed algorithmic model. Quarterly data on 10 housing price indices provided by the Federal Housing Finance Agency is used to estimate the factors underlying these markets for the period 1991Q1:2014Q4. The copula dependence parameters is then regressed on these factors to assess the non linear dependence between New York and Kansas housing markets which share a linear correlation coefficient of 0.28 during the period under review. The clayton dependence parameter, for instance, is now modelled as  $\theta_{cl} = 1 + plogis(\eta_1 * f_{local} + \eta_2 * f_{national} + \epsilon_t)$ , with the notations having their respective meanings.

The results in Table 1.4 show that the dependence pattern between these two markets is largely negative with the clayton copula bearing a weight of 0.84 in the algorithm and gaussian copula having a weight of 0.18. So this implies that these markets move together during downturns. As may be seen from the corresponding figure 1.1 which displays the time varying clayton copula dependence pattern during 1991Q1:2014Q4, the correlation spiked in the run up to the crisis and peaked in 2008, while remaining almost dormant for most of the 90s.

## ii) Offshore Markets in Indian Rupee

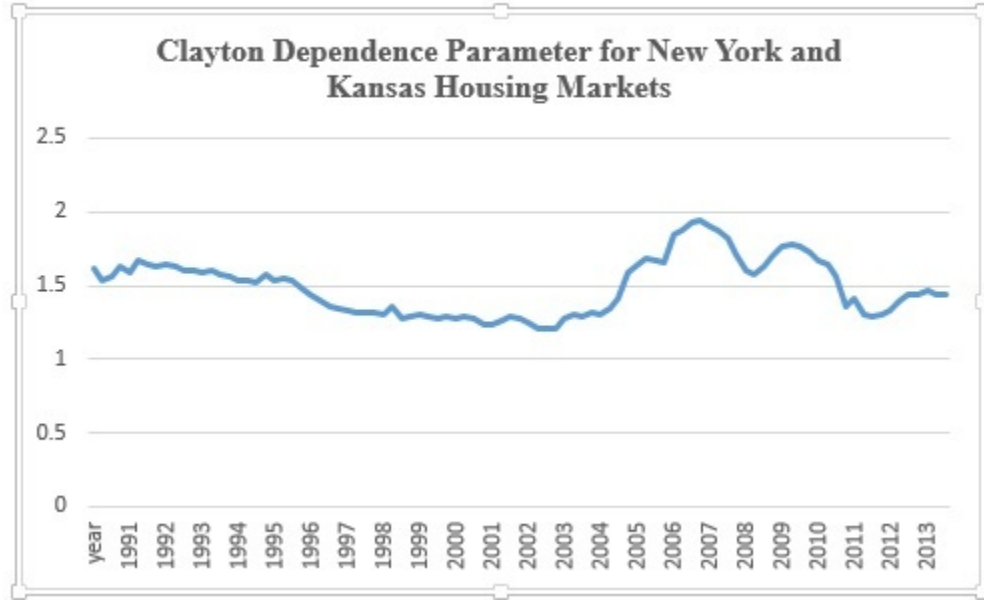


Figure 1.1: Varying Clayton Dependence

The second empirical application concerns the offshore markets in Indian rupee (INR). Basic statistical analysis of this market indicates large excess kurtosis of returns, particularly returns in the NDF market clearly indicate that the empirical distribution of the returns display fatter tails than the gaussian distribution. This is substantiated by the kernel densities of returns in these markets in Figures 1.2. It is clear that linear correlation cannot possibly completely define the dependence structure of these exchange rates.

Using daily data on returns in the offshore markets obtained from the Reuters database, the dependence parameters and weights on the copulas are modelled as an AR(1) process. The log difference in  $INR_{spot}$  is denoted as  $X_t$  while log difference in INR-NDF 1month is indicated as  $Y_t$ . As in Patton (2006), both are modelled as GARCH (1,1) with symmetric student t innovations

$$X_t = \mu_x + \varepsilon_t$$

$$\sigma_{x,t}^2 = \omega_x + \beta_x \sigma_{x,t-1}^2 + \alpha_x \varepsilon_{t-1}^2$$

Figure1: Kernel Densities of log Differences of INR Spot, INR 1Month Forward and NDF 1Month

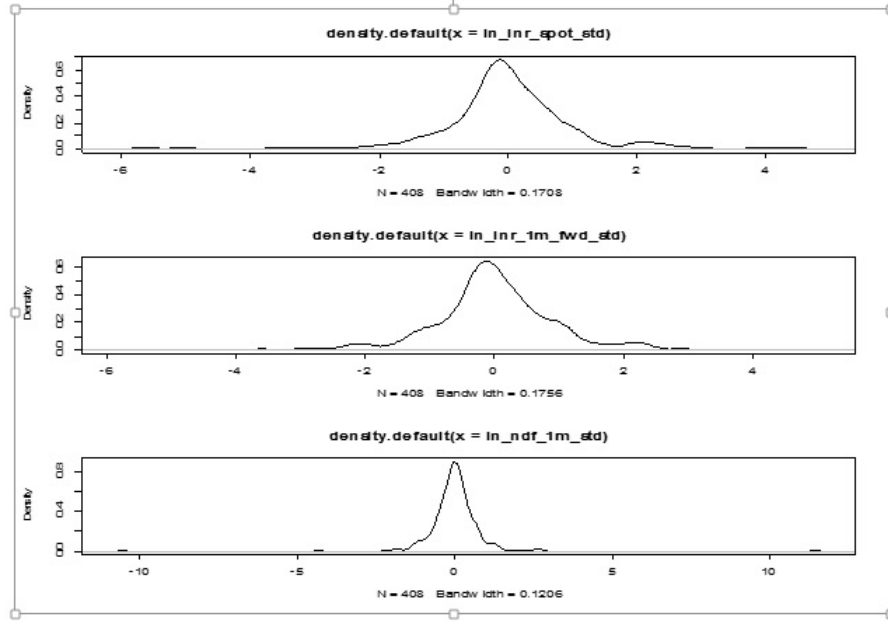


Figure 1.2: Kernel Densities of Returns in INR Spot and NDF Markets

$$\sqrt{\left(\frac{v_x}{\sigma_{x,t}^2(v_x - 2)}\right)} \cdot \varepsilon_t \sim i.i.d.t_{v_x}$$

$$Y_t = \mu_y + \eta_t$$

$$\sigma_{y,t}^2 = \omega_y + \beta_y \sigma_{y,t-1}^2 + \alpha_y \eta_{t-1}^2$$

$$\sqrt{\left(\frac{v_y}{\sigma_{y,t}^2(v_y - 2)}\right)} \cdot \eta_t \sim i.i.d.t_{v_y}$$

The results of the conditional marginal model are appended in Table 1.5 and the results of the estimation are given in Table 1.6.

The correlation in the INR-Spot and INR-NDF is characterised primarily by gaussian depen-



Table 1.5: **Results of Conditional Garch Models**

	INR-Spot Coeff	INR-Spot S.E	INR-NDF Coeff	INR-NDF S.E
Constant	0.012	0.007	0.015	0.009
w(x),w(y)	0.002	0.001	0.01	0.003
b(x),b(y)	0.889	0.02	0.818	0.025
a(x),a(y)	0.125	0.027	0.179	0.031
Shape Par	4.09	0.463	4.38	0.46

dence with the weight on the gaussian copula being 0.7 and that on the frank copula being 0.3 which has a similar dependence structure as gaussian copulas.

## 1.8 Estimation with Non-Parametric Weights

According to the Sklar's Theorem, the joint distribution is linearly associated with the component copulas which could involve some misspecification error. In this segment, in order to improve on the specification, the multivariate distribution is expressed as a combination of copulas with non-linear weights  $\lambda_k(\cdot)$  where  $(\lambda_k)_{k=1}^p$  are unknown functions

$$F(x; \alpha, \theta, \lambda) = \sum_{k=1}^p \lambda_k(\beta' Z_t) C_k(F_1(x_1; \alpha_1), \dots, F_n(x_n; \alpha_n); \theta_k) \quad (1.3)$$

In fact, Equation 1.3 can be treated as a special case of functional index coefficient models of Fan, Yao and Cai (2003). These models have a long history beginning with Ichimura (1993).

The model bears considerable economic relevance. The structure of bivariate distribution would be influenced by the structural changes in the economy. One way of depicting this would be to envisage that the composition of the joint distribution as borne out by the mixture of copulas with different dependence properties changes in line with the structural changes in the economy.

Table 1.6: **Coefficients on Weights and Dependence Parameters**

	weights	par on dependence	par on weights
Gaussian Copula	0.7001	-3.07	1.265
Clayton Copula	0	0	0
Frank Copula	0.299	-39.48	0.6
Gumbel Copula	0	0	0

This is expected to be reflected in the weights of the component copula functions. Hence the weights on copulas are modelled as unknown functions of structural variables. The ensuing model leads to a selection of mixed copula via penalized likelihood within the estimation of functional index coefficient models.

The estimation process involves two stages as demonstrated in Fan, Yao and Cai (2003) and Cai, Juhl and Yang (2014). One, estimation of function  $\lambda_j(\cdot)$  given  $\beta$  and estimation of index coefficient given  $\lambda_j(\cdot)$ . The copula selection process is embedded by an optimal choice of penalty function within this framework. Given  $\beta$ ,  $\lambda_j(\cdot)$  is first estimated by penalized local least squares localized around  $\beta'Z_t$ . At the second stage, given  $\lambda_j(\cdot)$ , a one step estimation scheme is employed as described in Fan, Yao and Cai (2003) to estimate  $\beta$ . Each of the stages is described below in detail.

### 1.8.1 Local Linear Estimation

Given an initial estimator  $\hat{\beta}$ , such that  $\hat{\beta} - \beta = O_p(1/\sqrt{(n)})$ , the penalized sum is minimized (Equation 1.4)

$$\sum_{t=1}^n [Y_t - \sum_{k=1}^p \lambda_k(\beta'Z_t) C_k(F_1(x_1; \alpha_1), \dots, F_n(x_n; \alpha_n); \theta_k)]^2 K_h(\beta'Z_t - z) w(\beta'Z_t) + n \sum_{j=1}^p P_{\gamma_n}(\hat{\lambda}_{\cdot j}) \quad (1.4)$$

A local linear estimator is used to estimate the functions  $\lambda_0(\cdot), \dots, \lambda_{p-1}(\cdot)$ . This amounts to minimising the sum of squares of (Equation 1.5)

$$\sum_{t=1}^n [Y_t - \sum_{j=0}^{p-1} (b_j + c_j(\beta'Z_t - z))C_j]^2 K_h(\beta'Z_t - z)w(\beta'Z_t) + n \sum_{j=1}^p P_{\gamma_n}(\hat{\lambda}_{.j}) \quad (1.5)$$

with respect to  $[b_j]$  and  $[c_j]$  where  $\hat{\lambda}_j(z) = \hat{b}_j$ ,  $\hat{\lambda}_j = \hat{c}_j$  for  $j = 0 \dots p-1$  and set

$$\hat{\theta} = (\hat{b}_0 \dots \hat{b}_{p-1}, \hat{c}_0 \dots \hat{c}_{p-1})^T$$

In equation 1.5 above,  $K(\cdot)$  is the epanechnikov kernel,  $K(x) = 3/4(1-x^2)$  if  $abs(x) \leq 1$ ,  $P_{\gamma_n}$  is the SCAD penalty function and  $(\gamma_1, \dots, \gamma_n)$  are the tuning parameters. The SCAD penalty function enjoys some desirable properties of a good penalty function namely unbiasedness, sparsity and continuity (Fan and Li, 2001).

The normal equations derived from the minimization of equation 1.5 with respect to  $[b_j]$  and  $[c_j]$  are given as

$$\begin{aligned} -2 \sum_t (Y_t - b_j - c_j(\beta'Z_t - z)C_j) K_h(\beta'Z_t - z)w(\beta'Z_t) &= 0 \\ -2 \sum_t (Y_t - b_j - c_j(\beta'Z_t - z)C_j) K_h(\beta'Z_t - z)w(\beta'Z_t)(\beta'Z_t - z)C_j &= 0 \end{aligned}$$

The estimated coefficients can then be written as

$$\hat{\theta} = \Sigma(z)\chi^T(z)W(z)Y$$

where  $\chi(z)$  is an  $n \times 2p$  matrix with  $((C_f, C_c, C_g, C_n)^T, (\beta'Z_t - z)(C_f, C_c, C_g, C_n)^T)$ ,  $W(z)$  is an  $n \times n$  diagonal matrix with  $K_h(\beta'Z_t - z)w(\beta'Z_t)$  as its  $i$ -th diagonal element and  $\Sigma(z) = [\chi'(z)W(z)\chi(z)]^{-1}$  and  $Y = (Y_1, \dots, Y_n)$ .

## 1.8.2 Search for Index Coefficient

Given the estimator of  $\hat{\lambda}_j(\cdot)$ ,  $\beta$  is searched for by minimizing the global least squares

$$V(\beta) = \frac{1}{n} \sum_{t=1}^n [Y_t - \sum_{k=1}^p \lambda_k(\beta' Z_t) C_k(F_1(x_1; \alpha_1), \dots, F_n(x_n; \alpha_n); \theta_k)]^2 w(\beta' Z_t) \quad (1.6)$$

Unlike Cai, Juhl and Yang (2014), the least squares is not penalized to choose locally significant variables. Instead, the choice of variables is left to economic intuition. The one-step estimation procedure is used to estimate  $\beta$  just like Newton Raphson estimation.

$$\beta^{(1)} = \beta^{(0)} - \ddot{V}((\beta)^{(0)})^{-1} \dot{V}(\beta)^{(0)} \quad (1.7)$$

The first and second derivatives of  $V(\beta)$  can be calculated as

$$\begin{aligned} \dot{V}(\beta) = & (-1) \frac{2}{n} \sum_{t=1}^n (Y_t - \sum_{k=1}^p \lambda_k(\beta' Z_t) C_k) \left( \sum_{k=1}^p \dot{\lambda}_k(\beta' Z_t) C_k Z_t \right) w(\beta' Z_t) \\ & + n \sum_{k=1}^p P_\gamma[0.5(\sum_n \lambda_k^2(\beta' Z_t))^{-0.5} (2 \sum_n \lambda_k(\beta' Z_t) \dot{\lambda}_k(\beta' Z_t) Z_t)] \quad (1.8) \end{aligned}$$

$$\begin{aligned} \ddot{V}(\beta) = & (-1) \frac{2}{n} \sum_{t=1}^n (Y_t - \sum_{k=1}^p \lambda_k(\beta' Z_t) C_k) \left( \sum_{k=1}^p \ddot{\lambda}_k(\beta' Z_t) C_k Z_t^2 \right) w(\beta' Z_t) \\ & + \frac{2}{n} \left( \sum_n \dot{\lambda}_k C_k Z_t \right)^2 w(\beta' Z_t) + \\ & n \sum_{k=1}^p P_\gamma[-0.75(\sum_n \lambda_k^2(\beta' Z_t))^{-1.5} (2 \sum_n \lambda_k(\beta' Z_t) \dot{\lambda}_k(\beta' Z_t) Z_t)^2 + \\ & 0.5(\sum_n \lambda_k^2(\beta' Z_t))^{-0.5} (2 \sum_n [\lambda_k(\beta' Z_t) \ddot{\lambda}_k(\beta' Z_t) Z_t]^2 + (\dot{\lambda}_k Z_t)^2)] \quad (1.9) \end{aligned}$$

### 1.8.3 Penalty Function

The SCAD penalty function proposed by Fan and Li (2001) is used which satisfies all the three desired properties of a good penalty function.

### 1.8.4 Choosing Bandwidth and Tuning Parameters

The process described in Cai, Juhl and Yang (2014) is followed for choosing the regularization parameters - bandwidth  $h$  for non-parametric estimator and tuning parameters for penalty terms. They are chosen simultaneously with BIC-type criterion given as

$$BIC(h, \gamma) = \log(SSE(h, \gamma)) + df(h, \gamma)\log(n)/n$$

where  $SSE(h, \gamma)$  is the sum of squared errors from the penalized least squares estimation and  $df(h, \gamma)$  is the number of non-zero beta coefficients conditional on  $h$  and  $\gamma$ . Since it is computationally exhorbitant to choose  $p$ -dimensional tuning parameters, the idea in Fan and Li(2004) is adopted to reduce the dimension of tuning parameters. So let  $\gamma_n = \gamma_0 \hat{\sigma}(\hat{\beta}_k^0)$ , where  $\hat{\sigma}(\hat{\beta}_k^0)$  is the standard deviation of the unpenalized index coefficient.

## 1.9 Simulations

The data generating process consists of a bivariate distribution which has the form of copula viz.,  $(u_t, v_t)$  i.i.d  $C(u, v; \theta)$ . The marginal distributions are empirically distributed. The working mixed copula model is written as

$$F(x; \theta, \lambda) = \lambda_g(\beta'Z_t)C_g(F_1(x_1), \dots F_n(x_n); \theta_g) + \lambda_f(\beta'Z_t)C_f(F_1(x_1), \dots F_n(x_n); \theta_f) + \lambda_{gu}(\beta'Z_t)C_{gu}(F_1(x_1), \dots F_n(x_n); \theta_{gu}) + \lambda_{cl}(\beta'Z_t)C_{cl}(F_1(x_1), \dots F_n(x_n); \theta_{cl}) \quad (1.10)$$

Data are generated from the four single copulas, Gaussian (g), Frank (f), Gumbel (gu) and Clayton (cl). Thus the weight corresponding to the copula in the actual model is 1 as opposed to the working model. 500 simulations are conducted each for sample sizes of 200, 400 and 1000 and varying coefficients are computed following the above mentioned DGP and the algorithm elabo-

Table 1.7: **Simulation Results - Non-parametric Weights**

	n=200		n=400		n=1000	
	Shrinking Rate	Keeping Rate	Shrinking Rate	Keeping Rate	Shrinking Rate	Keeping Rate
Gaussian	100%	100%	100%	100%	100%	100%
Frank	90.20%	90.20%	91.4%	95.50%	91.4%	96.20%
Gumbel	100%	100%	100%	100%	100%	100%
Clayton	100%	100%	100%	100%	100%	100%

rated above. The simulation results demonstrate the shrinkage rate and keeping rate of functional coefficients. The shrinkage rate may be defined as the percentage that the three functional coefficients correctly shrink to zero. The keeping rate may be defined as the percentage that the only non-zero coefficient does not shrink to zero.

## 1.10 Empirical Application

In another exemplary demonstration of unconventional monetary policy (UMP), five countries spread over Europe, Scandinavia and Japan introduced negative policy interest rates in the last few years. Among several aspects, transmission of negative policy rates to other rates in the money market post the shift in monetary policy regime has triggered increased interest. Whether banks have passed on the low interest rates to consumers in the form of low deposit rates to households and lower loan rates to firms is a million dollar question these days.

Preliminary reports suggest that negative policy rates are transmitted to money market rates in the same way as positive rates (BIS, 2016). In this section, the money market integration in these countries is explored through the period 1997Q1 to 2016Q4, spanning various structural changes in the financial sector. A mixed copula method is used with non-parametric weights developed in the previous section to model the joint distribution of policy rates and other money market rates in the paper. The results of the application for Denmark is demonstrated below in the form of Figure 1.3 and Figure 1.4.

Figure 1.3 clearly illustrates that the share of normal and frank dependence in the bivariate

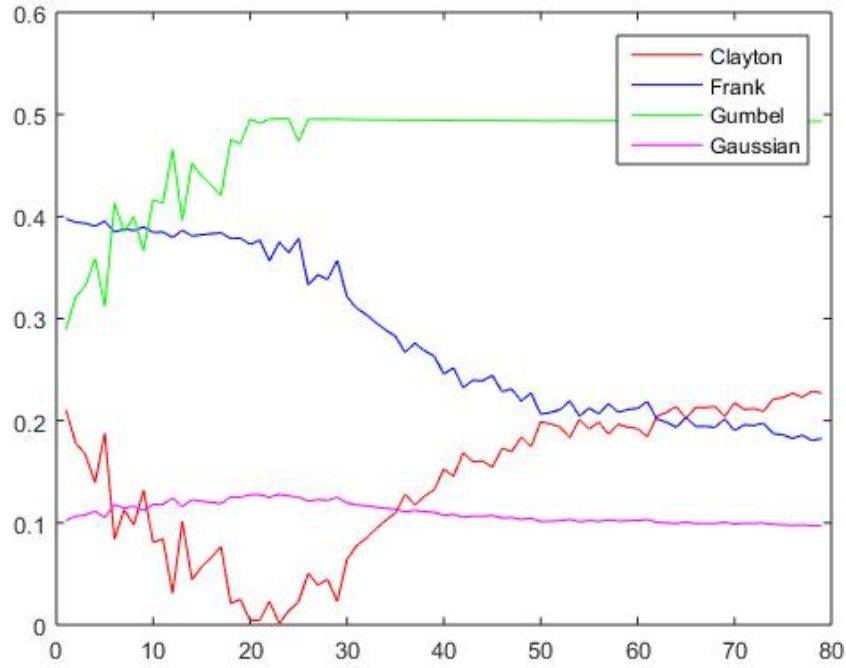


Figure 1.3: Varying Coefficient Weights

distribution has been declining post crisis with a compensating rise in the presence of copulas with extreme dependence properties. While share of gumbel copula dependence has been rising from the beginning and plateaued after a point, lately the bivariate distribution of short and long run interest rates in Denmark has been showing evidence of negative dependence through the rise of the weight on the clayton copula. We make 1000 draws from the estimated copula which is exhibited in the form of a scatter plot in Figure 1.4. The value of  $\beta$  for Denmark is 0.895 and is statistically significant as illustrated by bootstrap standard errors. The positive sign on the coefficient is suggestive of the fact that higher the share of financial system in the GDP, the stronger is the money market integration.

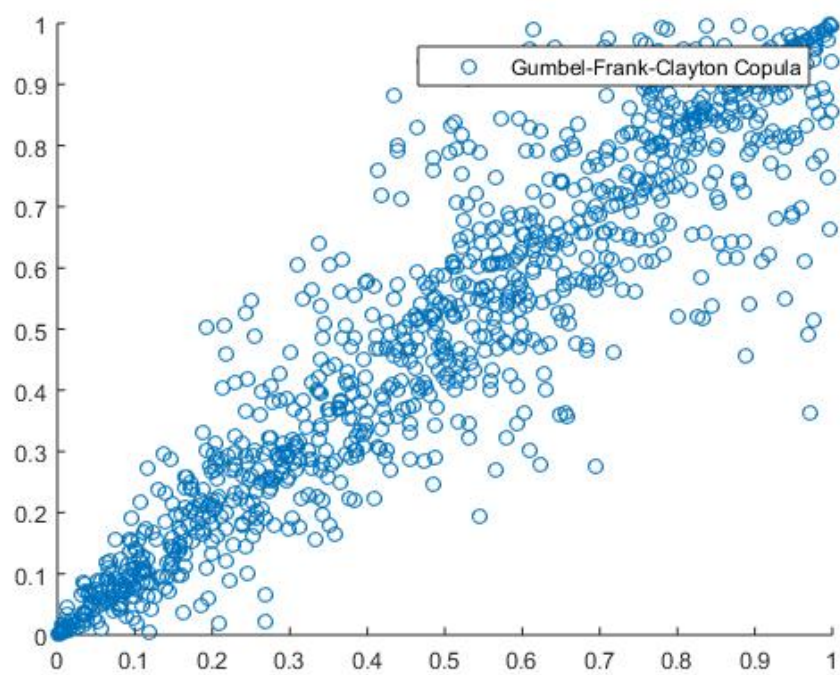


Figure 1.4: Random Draws from the Mixed Copula



## **Chapter 2**

### **Can We Still Lean Against the Wind?**

#### **Asset Price Volatility and Optimal Policy Mix in Overlapping Generations Model**

##### **2.1 Introduction**

Policy responsiveness to asset bubbles has been a subject of protracted debate among policy makers and researchers alike for decades. The debate acquired renewed synergy during the global crisis. A prevailing view during the late nineties was that monetary policy should not target asset prices directly because it aggravates economic fluctuations but should rather focus on achieving price stability and fortifying financial systems to survive asset price instability (Crockett 1998; Bernanke and Gertler, 2000). In fact, this literature saw little incremental value in adding asset prices to monetary policy rules in terms of its contribution towards stabilizing output and inflation. Price stability and financial stability were viewed as consistent and mutually reinforcing objectives and strong monetary policy response to inflation as a sufficient instrument to contain the impact of asset bubbles (Bernanke and Gertler, 2000; Gilchrist and Leahy, 2002). In sharp contrast, according to another school of thought, central banks response to asset bubbles was regarded as imperative provided they carry non-trivial information in determining output and inflation (Goodhart and Hofmann, 2000a; Goodhart and Hofmann, 2000b; Filardo; 2001). In this case, a proactive monetary restriction or 'leaning against the wind' policies may be construed as an optimal policy when the risk of a bust is large and the monetary authorities can defuse it at a relatively low cost in terms of output and inflation sacrifices (Bordo and Jeanne; 2002).

There is also an extant view that has gained popularity during the crisis. According to this view, monetary policy is a blunt instrument in the sense that it may entail larger output and employment losses unless there is a general macroeconomic overheating (Crowe et al; 2013). In fact, a closely held view is monetary policy may not directly affect the bubble component of demand as it tends to have a life of its own with less responsiveness to changes in policy rates due to inefficiencies in asset markets (real estate) that allow positively serially correlated returns (Case and Shiller, 1989). Amidst this debate, Gali (2014), in fact, questioned the theoretical validity of 'leaning against the wind' monetary policy response to asset bubbles. In a partial equilibrium analysis in his paper, Gali (2014) has shown that while monetary tightening might lower the fundamental component of asset price ( $Q_t^f = E_t(\sum_{k=0}^{\infty} (\prod_{j=0}^{k-1} (1/R_{t+j})) D_{t+k})$ ) where  $R$  is the interest rate and  $D$  is the dividend flow), contrary to conventional wisdom,, the ensuing rise in interest rates will raise the expected growth of the bubble component. In a general equilibrium analysis with nominal rigidities following this, Gali (2014) has shown central bank response to asset bubbles operating through the Taylor rule aggravates volatility of bubbles. Thus any optimal monetary policy might have to strike a balance between stabilization of aggregate demand which requires a positive interest rate response to the bubble and stabilization of the bubble itself and hence future aggregate demand which requires a negative interest rate response. If the size of the bubble is large enough, stabilization of the bubble would be a predominant motive, making it optimal for the central bank to lower interest rates to reign in a growing bubble.

In addition, a large segment of authors also propose that policy responsiveness to bubble should depend on the type of the bubble and this literature leads to a different policy perspective. Studies have illustrated that phases of bubble booms have been preceded by credit expansion which finds its way into assets in fixed supply such as real estate and stocks and credit financed bubbles cause deeper recessions and gradual recoveries (Allen and Gale, 2000; Kannan et al, 2009; Jorda et al; 2015, Brunnermeier and Schnabel; 2015, Miao and Wang; 2015). Thus while price stability may promote financial stability, it concomitantly increases the likelihood that excess demand pressures express first in terms of credit aggregates and asset prices rather than goods and services prices (Bo-

rio and Lowe, 2002). Hence, there is an emerging view that while monetary policy should solely be concerned with price stability, financial stability should be handled through microprudential and macroprudential regulation. In fact, principal-agent problems, overwhelming changes in the mode of contagion and 'disaster myopia' theory that surfaced during the recent crisis, attribute an indomitable niche of operation of macroprudential policy (Davis and Karim, 2010). While earlier credit risk led to contagion, either through direct exposures or uncertainties on account of ambiguous balance sheets, today contagion occurs via changes in market prices, measuring of risks and mark-to-market practices in commercial banks which are more typical of investment banks (Shin, 2008). Macroprudential surveillance becomes necessary to avoid the building up of off-balance sheet risks during monetary/fiscal bailout of weak financial institutions which share strategic complementarities with their peers (Farhi and Tirole, 2009).

Post 2008 crisis, the emerging view about the 'risk taking' channel of monetary policy transmission has brought to the fore the coordination dimension of the monetary-macroprudential policy interaction. The risk-taking channel asserts that pass-through of monetary policy impulses depends on the perception of risk and risk tolerance of economic agents. The evolving macroprudential regulatory capital framework plays a significant role in mapping monetary policy impulses into ultimate bank portfolio and lending decisions through twin channels - capital threshold effect and capital framework effect. Thus transmission of monetary policy impulses hinges on how the bank perceives, manages and prices risks given the characteristics of the capital framework, the capital cushion, underlying macroeconomic conditions and banks sensitivity to external financial constraints (Borio and Zhu, 2008).

In the backdrop of these plethora of contrasting opinions on the subject, this paper revisits the question, if Central Banks/regulatory authorities react to bubbles, what should be the policy instrument. More significantly, should the Central Bank track the bubble directly using the nominal interest rate (by introducing the misalignment in the price of the bubbly asset *vis-a-vis* the fundamental in the monetary policy feedback rule) or is it more effective to take an indirect route and track and temper the credit growth rate by influencing commercial bank's cost of credit using

macro-prudential policy. The question assumes significance in the light of both past comments in theoretical analysis on the subject as well as current discourse on the subject. Bernanke and Gertler (2000) have already pointed out that if capital markets are efficient and regulatory distortions are absent, movements in asset prices simply reflect changes in underlying economic fundamentals. Asset price volatility become an independent source of economic instability if non-fundamental factors arising from poor regulatory practice and irrational behaviour underlie asset price movements. In that case, the need for regulatory correction or an optimal mix of both monetary and prudential policy cannot be overemphasized. Further, macroprudential surveillance is inevitable given the 'financial fragility view' (Minsky; 1978) and 'disaster myopia' view. In the light of credit emerging as a predominant factor behind speculative investment and the limitations of monetary policy, it is reasonable to look beyond monetary policy instruments.

This paper extends Gali(2014) to explore the theoretical justification of macroprudential policy response to asset bubbles. Gali (2014) stopped short of introducing a financial sector in his model and he left it as a future research agenda. This paper takes forward Gali's(2014) work by introducing credit frictions in his overlapping generations model with nominal rigidities, monopolistic competition, heterogeneous agents and bankers. The main results from the paper may be summarized as under

1. The model with credit frictions nests Gali(2014) results. One, monetary policy cannot influence the conditions for existence of a bubble, but it can influence the size and volatility of bubble fluctuations. Two, a stronger interest rate response to bubble fluctuations such as leaning against the wind policies may raise the volatility of asset prices and of their bubble component.
2. Macro-prudential policy influences the conditions for existence of a bubble as well as its size and volatility of fluctuations.
3. Minimisation of bubble fluctuations requires an active macro-prudential policy. However, very tight macroprudential policy may induce banks to take higher risks which can be coun-

terproductive.

4. In terms of monetary policy, like Gali (2014), there is conflict between stabilization of current aggregate demand and future aggregate demand.
5. However, optimal macro-prudential policy may not have to strike a balance between stabilization of current aggregate demand (which call for a negative response to the bubble) and stabilization to the bubble itself (stabilization of future aggregate demand) which demands an increasing response to the bubble, at least upto a threshold.

The paper is organised as follows. Section 2 describes the literature on the subject. Section 3 lays down the framework of the overlapping generations model. Section 4 and Section 5 describe the equilibrium conditions and dynamics of the deterministic case, respectively. Section 6 lays down the log-linearized conditions of the stochastic model and the various sub-sections analyse the flexible and sticky price cases. Section 7 describe the optimal policy experiments. Section 8 presents the empirical set up using vector autoregression (VAR) to validate the theoretical findings. Section 9 concludes.

## **2.2 Literature Review**

This paper relates to a wide arena of existing literature in asset bubbles and various macroeconomic policies to manage bubbles. The traditional literature on rational bubbles is directly traceable to Samuelson (1958) and taken forward by Tirole (1985) where he analyzed conditions for existence of rational bubbles in a production economy. The role of bubbles in these models was to reduce inefficient investments and prevent dynamic inefficiency. However, the theoretical results of Samuelson (1958) and Tirole (1985) pointed towards a decline in investment and output during bubbly episodes which was inconsistent with the macroeconomic data that characterizes the bubbly episodes. Martin and Ventura (2012) resolved this disconnect by introducing investor sentiment shocks and imperfect financial markets into the theory of rational bubbles. They showed that bubbly episodes not only reduce inefficient investments but also raise efficient investments,

thereby raising total investment and output, if the latter effect predominates. Martin and Ventura (2014) added a credit market to the Tirole (1985) model and differentiated between fundamental and bubbly collateral to show how investor optimism drives up the stock of bubbly collateral to relax the collateral constraint giving rise to bubbles and credit and investment boom (crowding-in effect), while investor pessimism can engineer a bubble burst, credit contraction and recession.

Miao and Wang (2011) developed a theory of credit driven stock price bubbles in production economies in an infinite horizon model where the credit constraint is derived endogenously from the incentive constraint in an optimal contracting problem. The collateral value of the firm is derived from the incentive constraint as a going concern value of the firm which is priced in the stock market and may contain a bubble as opposed to the more familiar liquidation value of the collateralised assets (Kiyotaki and Moore (1997)). Optimistic beliefs of both the borrower and the lender that collateral value is driven by bubbles generates a positive feedback loop that makes their beliefs self-fulfilling allowing bubbles to exist in their model. Some authors (Kocherlokota (2009), Miao et al (2015)) also considered bubbles on land, which although an intrinsically useless asset, serves as a collateral. Miao et al (2015) find that land bubble can generate inefficient overinvestment reducing welfare in the net. Kocherlokota (2009) demonstrate that collapse of a land bubble may lead to unrecoverable and immediate adverse impact on aggregate variables.

Contrary to Gali (2014), a number of papers have found support for active monetary policy response to asset bubbles. Loisel et al (2009) find that asset bubbles that result from herd behaviour in investment in a new technology whose productivity is uncertain can be prevented through tight monetary policy intervention that makes borrowing expensive by entrepreneurs. Using an overlapping generations exchange economy model with portfolio choice between money and bubble, Yvgard and Seegmuller (2015) find that a monetary policy rule incorporating asset prices can locally and globally stabilize fluctuations in contrast to rules that respond exclusively to inflation. On the other hand, there is also substantial evidence supporting Gali(2014)'s views on monetary policy response to the asset bubble. Faia and Monacelli (2007) study the role that asset prices should play in optimal setting of monetary policy rules in an economy with nominal rigidities and

credit market frictions following the agency cost framework of Carlstrom and Fuerst (1997). They conclude that central banks should react to asset price bubbles by lowering interest rates. They view asset prices as a tax that responds procyclically to positive productivity shocks distorting evolution of investment. In a DSGE model context incorporating household debt dynamics, Gelain et al (2015) have found that a systematic monetary policy response to an increasing debt-GDP ratio or real debt levels, causes equilibrium indeterminacy and aggravates the volatility in the debt itself.

The paper is also related to a large body of research evaluating the monetary and macroprudential policy measures to manage bubbles. Martin and Ventura (2014) argue that a lender of last resort can replicate an optimal bubble allocation by adopting 'leaning against the wind' policy by taxing credit when bubbly collateral is excessive and subsidizing it when it is inadequate. In a historical analysis of bubbles, Brunnermeier and Schnabel (2016) have asserted that monetary and macroprudential measures that lean against inflating bubbles are more effective in deflating bubbles and associated economic crises. Extending the Doherty-Madrigal (2012) model by adding a credit market as a source of funds that fuels bubbles, Madrigal and Lansing (2016) show that for LTV caps below a certain threshold generates equilibria without risk shifting. Thus contractionary monetary policy coupled with subdued LTV ratios can eliminate bubbles in their model. In the context of analysing the dynamics of housing price and current account, Mendicino and Punzi (2014) conclude that a welfare improving policy mix consists of an interest rate response to credit and LTV ratio that countercyclically responds to housing price movements. Crowe et al (2013) present a very clear perspective on the use of monetary and macroprudential policy to manage bubbles. They recommend that monetary policy must be used as a complementary instrument and with a leaning against the wind approach to ensure that macroprudential instruments are effective. The optimal design of macroprudential policy would be to have robust rules that accommodates discretion when necessary enabling calibration to specific situations. In sharp contrast, Cecchetti and Kohler (2012) show that monetary and macroprudential policies are perfect substitutes and any instrument can be used to address the macroeconomic and financial stability objectives. If financial stability is an outcome of sector specific shocks, then capital requirements are an appropriate tool

to address it. On the other hand, interest rates can reach parts of financial intermediation which are not under the regulatory purview. Using Fisherian debt-deflation model, Bianchi and Mendoza (2015) find that an effective optimal macroprudential policy requires significant variation across regimes of global liquidity and realizations of news shocks. The effectiveness of the policy varies non-monotonically with the precision in the news about future income. When precision is low, effectiveness of policy improves as precision rises. But when precision is high, financial crisis occur with lower probability and hence effectiveness of the policy falls with further rise in precision.

This paper is in spirit close to a number of other papers that study the interaction of monetary and macroprudential policy and its impact on macroeconomic fluctuations but not necessarily asset bubbles. Angeloni and Faia (2009) study a sticky price macro model with a fragile banking sector. They recommend that mildly anticyclical capital ratios coupled with optimal monetary policy rule that responds to bank leverage or asset prices can reduce macroeconomic fluctuations. Collard et al (2012) derive jointly optimal policies using a model that views bank capital requirements as a tool for addressing the risk taking incentives created by limited liability and deposit insurance. They argue that locally optimal mandate of prudential policy is to ensure bank never funds inefficient risky projects that accomplish their objectives with minimal damage in terms of increased bank lending rates and decreased capital stock. And this distortion is minimized when capital requirement is state dependant. Paoli and Paustian (2013) study the monetary-macroprudential policy coordination in a New Keynesian model with nominal rigidities and credit frictions. They find that introduction of macroprudential policy targeted directly at the credit market distortions substantially improve welfare and coordination with monetary policy following cost push shocks. In the context of analysing the nexus between central bank policy and real housing prices in New Zealand, Shi et al(2014) have pointed out that real fixed interest rates do not have the desired contractionary impact on real housing prices after controlling for household mortgage choice and various economic conditions. Instead, mortgage rates, and within that fixed mortgage rates bear a larger impact on housing prices. The paper recommends that policy makers should use macroprudential instruments such as lowering down payment levels and capping LTV ratios to influence



the housing market particularly when the economy is open and central bank observes inflation targeting. Using a sign-restricted VAR, Greenwood-Nimmo and Tarassow (2016) have found that a contractionary monetary policy alone may raise financial fragility, while a macroprudential policy alone may not successfully reduce debt burden under fixed interest rates. But a coordinated policy with interest rates adjustment, macroprudential policy shock may reduce financial fragility enhancing financial stability. Many papers also find that welfare is higher, compared to a standard Taylor rule, in regimes where policymakers respond to financial imbalances using the policy rate or macroprudential rule (Bailliu et al, 2015)<sup>1</sup>.

In contrast with the earlier literature in rational bubbles, this paper considers the optimal monetary and macroprudential policy in an overlapping generations model in a production economy with banks and financial frictions. The paper works out the optimal policy mix that strikes a balance between stabilization of the bubble and stabilization of aggregate demand. In a similar spirit, Madrid and Lansing (2016) assess the appropriateness of monetary and macroprudential policy impact on credit-fuelled bubbles but their model falls short of having implications for optimal policy. Further, unlike this paper, their model does not consider financial intermediation through banks. The inclusion of the banking sector in the present paper with regulatory friction enables a study of the behaviour of the banks with respect to different levels of capital adequacy parameter. Angelini and Faia (2009), Collard et al (2012), Paoli and Paustian (2013) and others as detailed above also study monetary and macroprudential policy coordination but with respect to its implications for the broader macroeconomy without any specific reference to asset bubbles. The paper also distinguishes itself from papers like Miao and Wang (2015) and Miao et al (2015) which derive collateral constraints from optimal contracting problem. This paper assume that debt repayments are perfectly enforced.

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<sup>1</sup>For a review of literature on macroprudential policy, please see Galati and Moessner(2011)

## 2.3 Model

Consider a canonical 2-period Samuelson overlapping generations economy with an infinite sequence of generations. Each generation contains a continuum of individuals of size one, indexed by  $i \in I_t$ . Individuals maximize their lifetime expected utility according to the following log utility function

$$\max.[\log(C_{1,t}) + \beta E_t(\log(C_{2,t+1}))]$$

where  $C_{1,t}$  and  $C_{2,t}$  are the consumption when young and old and are defined as in Gali (2014). Like Gali(2014), assume that each individual is endowed at birth with  $\delta \in [0, 1]$  units of intrinsically useless assets whose price is strictly positive,  $Q_{t|t} > 0$ . Cases of  $Q_{t|t} < 0$  are ignored in line with the theory that admits free disposal. Each period a fraction  $\delta$  of each vintage of bubbly assets is assumed to lose value *i.e* physically destroyed so that total amount of bubbly assets outstanding remains constant and equal to one (Gali (2014)).

Each period, a subset  $I_t^E \subseteq I_t$  of households become entrepreneurs and start new firms, while the remaining set of households are called non-entrepreneurs. The entrepreneurs possess the knowledge of how to produce differentiated goods. So in each period, there is a continuum of differentiated goods available each produced by a different firm with a constant elasticity of substitution,  $\eta$ . Each firm becomes operational in period 1 and the technical specification is given as.

$$Y_t(i) = N_t(i) \quad i \in [0, 1] \tag{2.1}$$

To highlight the supply side of credit, a fixed number of agents distinct from consumers, termed bankers, who are infinitely lived and risk neutral are introduced. The bankers issue deposit liabilities to non-entrepreneurial households at the beginning of each time period and provide financial capital to entrepreneurs. I also assume, like Gali(2014) that there exists a market where the bubbly

assets introduced by both current and previous cohorts can be traded by both entrepreneurs and non-entrepreneurs.

All markets open at the beginning of the period and agents enter into contracts at the beginning of the period. Receipts for work and lending and payment for consumption in period  $t$  occur at the end of the period. All decisions are taken at discrete points in time.

### 2.3.1 Households

Each young non-entrepreneur sells his labor services inelastically for a real wage,  $W_t$ . He allocates his total cash inflow at time  $t$  consisting of his real wage and asset endowment into consumption ( $C_{1,t}^{NE}$ ), bank deposits ( $d_t$ ) yielding a nominal deposit interest rate of  $i_t^d$  and a variety of bubbly assets introduced by both current and previous cohorts. We also assume that non-entrepreneurs are stakeholders in firms and receive dividends in old age. The budget constraint for the young non-entrepreneur at time  $t$  is given as

$$\int_0^1 \frac{P_t(i)C_{1,t}^{NE}(i)}{P_t} di + \frac{d_t}{P_t} + \sum_{k=0}^{\infty} Q_{t|t-k}^B Z_{t|t-k}^B = W_t + \delta Q_{t|t}^B$$

During old age, the non-entrepreneur consumes all his wealth consisting of interest income from deposits, dividends from firms ( $D_t$ ) and capital gains. His budget constraint during old age is thus given as

$$\int_0^1 \frac{P_{t+1}(i)C_{2,t+1}^{NE}(i)}{P_{t+1}} di = D_{t+1} + (1 + i_t^d)^d \frac{d_t}{P_{t+1}} + (1 - \delta) \sum_{k=0}^{\infty} Q_{t+1|t-k}^B Z_{t|t-k}^B$$

Maximising expected utility subject to the above two constraints yields the following optimality conditions.

$$\beta_t^{NE} E_t \left[ \frac{(1 + i_t^d) C_{1,t}^{NE}}{C_{2,t+1}^{NE} \pi_{t+1}} \right] = 1 \quad (2.2)$$

$$Q_{t|t-k}^B = \beta(1 - \delta)E_t\left[\frac{C_{1,t}^{NE}}{C_{2,t+1}^{NE}}Q_{t+1|t-k}^B\right] \quad (2.3)$$

The entrepreneurs borrow  $b_t$  from the bank when young and allocate the proceeds of their loans and net worth on consumption, wage payment and asset purchases. Their budget constraint is given as

$$\int_0^1 \frac{P_t(i)C_{1,t}^E(i)}{P_t} di + \sum_{k=0}^{\infty} Q_{t|t-k}^B Z_{t|t-k}^{B,E} = \frac{b_t}{P_t} - W_t + \delta Q_{t|t}^B + y_t/m$$

During old age, the entrepreneur pays for his consumption expenditure and interest on the loans from the dividends from its firms and proceeds from the sale of bubbly assets.

$$\int_0^1 \frac{P_{t+1}(i)C_{2,t+1}^E(i)}{P_{t+1}} di + (1 + i_t^b) \frac{b_t}{P_{t+1}} = D_{t+1} + (1 - \delta) \sum_{k=0}^{\infty} Q_{t|t-k}^B Z_{t|t-k}^{B,E}$$

I first eliminate  $b_t$  by solving for  $b_t$  from the young entrepreneur's budget constraint and substituting in place of  $b_t$  in the old entrepreneurs budget constraint. The resulting constraint can then be substituted into the objective function to turn the problem into an unconstrained optimisation problem. The first order conditions emerging from the maximisation of the expected utility of entrepreneurs with respect to  $C_{1,t}^E$  and  $Z_t^B$  are then given as:

$$\beta_t^E E_t\left[\frac{(1 + i_t^b)C_{1,t}^E}{C_{2,t+1}^E \pi_{t+1}}\right] = 1 \quad (2.4)$$

$$Q_{t|t-k}^B = \beta^E (1 - \delta) E_t\left[\frac{C_{1,t}^E}{C_{2,t+1}^E} Q_{t+1|t-k}^B\right] \quad (2.5)$$

I assume that the entrepreneur cannot borrow more than his lifetime profit income i.e  $b_t \leq (m - 1)/2m$ . Lets define,  $R_t^d = \frac{(1 + i_t^d)}{\pi_{t+1}}$  and  $R_t^b = \frac{(1 + i_t^b)}{\pi_{t+1}}$ .

### 2.3.2 Firms

The firms are monopolistic competitors which sets the price of each good before the shocks are realised and this assumption is the source of nominal rigidities in the model as in Galí (2014). Thus at time  $t-1$  the firm sets the price of the good ( $P_t^*$ ) to be produced at time  $t$  by solving the following maximization problem,

$$\max. E_{t-1} \Theta_{t-1,t} Y_t \left( \frac{P_t^*}{P_t} - W_t \right)$$

subject to the demand schedule  $Y_t(i) = \left( \frac{P_t^*}{P_t} \right)^{-\eta} C_t$ , where  $C_t = C_{1,t}^{NE} + C_{2,t}^{NE} + C_{1,t}^E + C_{2,t}^E$ ,  $\Theta_{t-1,t} = \beta \left( \frac{C_{1,t-1}}{C_{2,t}} \right)$  which is the relevant discount factor. The optimal price setting rule is similar to Galí (2014) and given as

$$E_{t-1} \Theta_{t-1,t} Y_t \left( \frac{P_t^*}{P_t} - m W_t \right) = 0$$

$$\text{where } m = \frac{\eta}{\eta-1}$$

### 2.3.3 Bankers

The Bankers maximise profits subject to a simple balance sheet constraint. Bank profits at time  $t$  are generated from the difference in cash inflow on account of gross interest paid by generation  $(t-1)$  on loans offered during time  $(t-1)$  and the gross interest paid on deposit liabilities issued to generation  $(t-1)$  which matures in period  $t$ . Macroprudential policy imposes a restriction on financial intermediation that countercyclically affects the borrowing decision. As in Suh(2014), I assume that regulatory authority implements macroprudential policy by countercyclically changing the degree of regulation and banks face a cost when they fail to meet the regulatory requirement. This paper assumes that regulatory authority asks banks to set aside a countercyclical capital buffer which in turn imposes a cost that is increasing in the amount of loan assets held by banks,  $\phi^b b_t$  where  $\phi^b$  measures the central bank reaction to credit growth. Central Bank's macro-prudential policy 'leans against the wind' by reacting to abnormal credit growth.

$$Max.(P_t)$$

where

$$P_t = R_{t-1}^b b_{t-1} - b_t + d_t - R_{t-1}^d d_{t-1} - \phi^b b_{t-1}$$

subject to

$$b_t = d_t$$

The optimality condition with respect to bank's maximisation is given as

$$R_t^b = R_t^d + \phi^b \quad (2.6)$$

### 2.3.4 Monetary Policy Rule

The central bank sets the short term nominal deposit interest rate  $i_t^d$  according to the following rule.

$$1 + i_t^d = \bar{R}^d E_t(\pi_{t+1}) (\pi_t / \pi)^{\phi_\pi} (Q_t^B / Q^B)^{\phi_q}$$

where  $\pi_t$  is gross inflation and  $\pi$  is the target inflation rate. The real interest rate responds to fluctuations in inflation and aggregate bubble, with parameters  $\phi_\pi$  and  $\phi_q$ , where  $\phi_\pi > 0$  by assumption.

## 2.4 Equilibrium

The clearing of the market for each good requires that

$$Y_t(i) = C_{1,t}^E(i) + C_{1,t}^{NE}(i) + C_{2,t}^E(i) + C_{2,t}^{NE}(i) + \phi^b b_{t-1} \quad \forall i \in [0, 1], \quad \forall t$$

Like Gali (2014), define aggregate output as  $Y_t = \left( \int_0^1 Y_t(i)^{1-\frac{1}{\eta}} di \right)^{\frac{\eta}{(1-\eta)}}$  and using consumers

optimality conditions, the following expression in aggregate output is produced.

$$Y_t = C_{1,t}^E + C_{1,t}^{NE} + C_{2,t}^E + C_{2,t}^{NE} + \phi^b b_{t-1} \quad (2.7)$$

We assume all firms set identical prices and produce identical quantities in the symmetric equilibrium. Hence labor market clearing would imply

$$Y_t = \int_0^1 Y_t(i) di = 1 \quad (2.8)$$

Evaluating the optimal price setting condition under sticky price in symmetric equilibrium yields

$$E_{t-1}[(1/C_{2,t})(1 - mW_t)] = 0$$

which implies a constant real wage  $W_t = 1/m$

Asset market clearing conditions are similar to Gali (2014),

$$Z_{t|t-k}^B = \delta(1 - \delta)^k \quad (2.9)$$

The economy's aggregate bubble index and index for 'pre-existing' bubbles is also generated as per Gali(2014),

$$Q_t^B \equiv \delta \sum_{k=0}^{\infty} (1 - \delta)^k Q_{t|t-k}^B \quad (2.10)$$

$$B_t \equiv \delta \sum_{k=1}^{\infty} (1 - \delta)^k Q_{t|t-k}^B \quad (2.11)$$

Also,  $U = \delta Q_{t|t}$  denote the aggregate market value of newly introduced bubbles. The following equilibrium condition then follows from and previous definitions:

$$Q_t^B \equiv B_t + U_t = \beta E_t[(\frac{C_{1,t}^{NE}}{C_{2,t+1}^{NE}})B_{t+1}] \quad (2.12)$$

## 2.5 Dynamics

Let us start by assuming  $U_t = U > 0$  and  $B_t - E_{t-1}(B_t) = 0$  for all  $t$ . Under certainty, optimal price setting condition implies  $W_t = 1/m$ . Now from the income approach, since  $Y_t = 2D_t + W_t$ ,  $D_t = (m-1)/2m$ . The consumption of young and old non-entrepreneurs are given as  $C_{1,t}^{NE} = 1/m - b_t - B_t$  and  $C_{2,t}^{NE} = (1 - 1/m) + B_t + R_{t-1}^d d_{t-1}$ . The real interest rate is then given as

$$R_t^d = \frac{((1 - 1/m) + B_{t+1})}{(\beta^{NE}(1/m - B_t) - (1 + \beta^{NE})b_t)} = R^d(B_t, B_{t+1})$$

Equilibrium allocations can be determined given an equilibrium process for bubble  $B_t$  which must satisfy equilibrium condition for the bubble given as

$$\frac{(B_t + U)}{(1/m - b_t - B_t)} = \beta^{NE} \frac{B_{t+1}}{((1 - 1/m) + B_{t+1} + R_t^d b_t)}$$

Substituting  $R_t^d$  from above into the equation and rearranging, this equation produces the law of motion for the bubble. So a deterministic bubbly equilibrium is defined by a sequence  $B_t$  such that

$$B_{t+1} = \frac{(1 - 1/m)S_t(B_t + U)}{\beta^{NE}(1/m - B_t - b_t) - (B_t + U)S_t} = L(B_t, B_{t+1}) \quad (2.13)$$

where  $S_t = 1 + \frac{b_t}{\beta^{NE}(1/m - B_t) - (1 + \beta^{NE})b_t}$ .

with  $B_t \in [0, \frac{\beta^{NE}}{(1 + \beta^{NE})} \frac{1}{m} - \frac{(m-1)}{2m}] \forall t$  and some  $U \geq 0$ .

### 2.5.1 Stability Analysis

Like Gali (2014), we assume that the function  $L(B_t, U)$  abides by the following properties



1.  $L(B_t, U) \geq 0$  is twice continuously differentiable for  $0 \leq B < \frac{\beta^{NE}}{(1+\beta^{NE})} \frac{1}{m} - \frac{(m-1)}{2m} - \frac{U}{1+\beta^{NE}} = B^H$
2.  $\frac{dL(B_t, U)}{dB_t} = \frac{\beta^{NE} S_t (1-1/m)(1/m-B_t-b_t) + \beta^{NE} (B_t+U)(1-1/m) S_t + \beta^{NE} (B_t+U)(1-1/m)(1/m-B_t-b_t) \frac{\partial S_t}{\partial B_t}}{[\beta^{NE} (1/m-b_t-B_t) - (B_t+U) S_t]^2} > 0$  &  $\frac{d^2 L(B_t, U)}{dB_t^2} > 0$  for  $0 \leq B < B^H$
3.  $\frac{dL(B_t, U)}{dU} = \frac{\beta^{NE} S_t (1-1/m)(1/m-B_t-b_t)}{[\beta^{NE} (1/m-b_t-B_t) - (B_t+U) S_t]^2} > 0$  and  $\frac{d^2 L(B_t, U)}{d^2 U} = \frac{2\beta^{NE} S_t (1-1/m)(1/m-B_t-b_t)}{[\beta^{NE} (1/m-b_t-B_t) - (B_t+U) S_t]^3} > 0$  for  $0 \leq B < B^H$
4.  $\frac{d^2 L(B_t, U)}{dB dU} > 0$  for  $0 \leq B < B^H$

Consider the case of  $U=0$ , then  $B_t$  must satisfy

$$B_{t+1} = \frac{(1-1/m) S_t(B_t)}{\beta^{NE} (1/m-b_t-B_t) - S_t(B_t)} = L(B_t, 0)$$

Consider the case of bubbleless economy, *i.e* if  $B_t = 0$ , then steady state exists as  $L(0,0)=0$ . A necessary and sufficient condition for the existence of a bubbly steady state  $\bar{B}^U > 0$  such that  $L(\bar{B}^U, 0) = \bar{B}^U$  is  $\frac{dB_{t+1}}{dB_t} |_{0,0} < 1$  which leads us to the existence condition

Lemma 1 : A necessary and sufficient condition for existence of a deterministic bubbly equilibrium is

$$m < \frac{3(1+\beta^{NE})}{3+\beta^{NE}}$$

In this case,  $L(B_t, 0) > 0$  for any  $B_t > B^U$ . Thus the solution to  $B_{t+1} = L(B_t, 0)$  given an initial condition  $B_0 > B^U$  violates the constraint  $B_t < B^H$  and hence is not consistent with equilibrium. On the other hand,  $L(B_t, 0) < B_t$  for any  $B_t < B^U$  indicating that the solution to  $B_{t+1} = L(B_t, 0)$  given an initial condition  $B_0 < B^U$  converges to the bubbleless steady state  $B = 0$ . Hence,  $B^U$  is an unstable steady state.

It is also evident that at the bubbleless steady state,  $R^d(0) < 1$  which corresponds to the negative (net) real interest rate which makes the size of the aggregate bubble constant and consistent with

equilibrium.

## 2.6 Stochastic Version

To study the stochastic behaviour of the model, we log-linearize the system around the non-stochastic steady state derived in section 1. The log-linearized equilibrium conditions reads as under.

$$c_{1,t}^{\hat{N}E} = (c_{2,t+1}^{\hat{N}E}) - \hat{r}_t^d \quad (2.14)$$

$$c_{1,t}^{\hat{E}} = (c_{2,t+1}^E) - \hat{r}_t^b \quad (2.15)$$

The log-linearized budget equations can be written as

$$c_{1,t}^{\hat{N}E} = \gamma_{1w}^N \hat{w}_t - \gamma_{1b}^N \hat{B}_t - \gamma_{1d}^N \hat{d}_t \quad (2.16)$$

where  $\gamma_{1w}^N = \frac{\bar{W}}{\bar{C}_1^{NE}}$ ,  $\gamma_{1b}^N = \frac{\bar{B}}{\bar{C}_1^{NE}}$  and  $\gamma_{1d}^N = \frac{\bar{d}}{\bar{C}_1^{NE}}$

$$c_{2,t}^{\hat{N}E} = \gamma_{2D}^N \hat{D}_t + \gamma_{2B}^N \hat{B}_t - (R_{t-1}^{\hat{d}} + \hat{d}_{t-1}) \quad (2.17)$$

where  $\gamma_{2D}^N = \frac{\bar{D}}{\bar{C}_2^{NE}}$ ,  $\gamma_{2B}^N = \frac{\bar{B}}{\bar{C}_2^{NE}}$  and  $\gamma_{2R}^N = \frac{\bar{R}^d}{\bar{C}_2^{NE}}$

$$c_{1,t}^{\hat{E}} = \gamma_{1b}^E \hat{b}_t - \gamma_{1B}^E \hat{B}_t \quad (2.18)$$

where  $\gamma_{1b}^E = \frac{\bar{b}}{\bar{C}_1^E}$  and  $\gamma_{1B}^E = \frac{\bar{B}}{\bar{C}_1^E}$ .

$$c_{2,t}^{\hat{E}} = \gamma_{2D}^E \hat{D}_t + \gamma_{2B}^E \hat{B}_t - (R_{t-1}^{\hat{b}} + \gamma_{2R}^E \hat{b}_{t-1}) \quad (2.19)$$

where  $\gamma_{2D}^E = \frac{\bar{D}}{\bar{C}_2^E}$ ,  $\gamma_{2B}^E = \frac{\bar{B}}{\bar{C}_2^E}$  and  $\gamma_{2R}^E = \frac{\bar{R}^b}{\bar{C}_2^E}$

$$\hat{q}_t^B = \bar{R}^d \hat{B}_t + (1 - \bar{R}^d) \hat{u}_t = E_t \hat{B}_{t+1} - \hat{r}_t^d \quad (2.20)$$

$$\hat{r}_t^b = \frac{\bar{R}^d}{\bar{R}^b} \hat{r}_t^B \quad (2.21)$$

$$E_{t-1}(\hat{w}_t) = E_{t-1}(\hat{d}_t) = 0 \quad (2.22)$$

$$\hat{r}_t^d = \phi_\pi \hat{\pi}_t + \phi_q \hat{q}_t^B \quad (2.23)$$

$$\hat{B}_t = \bar{R}^d \hat{B}_{t-1} + (1 - \bar{R}^d) \hat{u}_{t-1} + \hat{r}_{t-1}^d + \zeta_t \quad (2.24)$$

$$(\hat{C}_{1,t}^{NE} + \beta^{NE} \bar{R}^d \hat{C}_{2,t}^{NE}) \bar{C}_1^{NE} + (\hat{C}_{1,t}^{NE} + \beta^E \bar{R}^b \hat{C}_{2,t}^E) \bar{C}_1^E + \phi^b \hat{b}_t = 0 \quad (2.25)$$

As in Gali (2014), assume that  $\zeta_t$  is a martingale difference stochastic process such that  $E_{t-1}(\zeta_t) = 0$ . It is an exogenous sunspot shock whose variance is independent of monetary policy.

Lets examine the flexible price case first. When firms adjust their prices once the shocks are realized, they optimally choose to maintain their gross mark-up  $m$  which in turn implies that the wage and dividend remains constant at their steady state values. Hence, equation 2.22 is replaced by the following

$$\hat{w}_t = \hat{d}_t = 0 \quad (2.26)$$

Combining equations (2.15), (2.18), (2.19) and (2.20) results in the following equation for real interest rate

$$\hat{r}_t^d = \frac{(\gamma_{1B}^E + \bar{R}^d \gamma_{2B}^E)}{(\gamma_{2R}^E \bar{R}^d - \gamma_{2B}^E)} \hat{B}_t - \frac{(\gamma_{1b}^E + \gamma_{2R}^E)}{(\gamma_{2R}^E \bar{R}^d - \gamma_{2B}^E)} \hat{b}_t + \frac{\gamma_{2B}^E (1 - \bar{R}^d)}{(\gamma_{2R}^E \bar{R}^d - \gamma_{2B}^E)} \hat{u}_t \quad (2.27)$$

It is evident from Equation (2.27) that under flexible prices, though real interest rates are independent of monetary policy parameters ( $\phi_\pi$  or  $\phi_q$ ), it is not independent of capital adequacy parameters which enters through  $\bar{R}^b$ . Substituting  $\hat{r}_t^d$  from equation 2.27 into equation 2.24, yields the law of motion of the bubble.

$$\hat{B}_t = (\bar{R}^d + \frac{(\gamma_{1B}^E + \bar{R}^d \gamma_{2B}^E)}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)}) \hat{B}_{t-1} - \frac{(\gamma_{1b}^E + \gamma_{2R}^E)}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)} \hat{b}_{t-1} + (1 + \frac{\gamma_{2B}^E}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)})(1 - \bar{R}^d) \hat{u}_{t-1} + \zeta_t \quad (2.28)$$

Stationarity of the bubble requires that the parameter  $\lambda = [(\bar{R}^d + \frac{(\gamma_{1B}^E + \bar{R}^d \gamma_{2B}^E)}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)})]$  lies in  $[0, 1)$ . Due to its inability to impact the real interest rate, monetary policy has no influence on the evolution of the bubble. But the law of the motion of the bubble depends on credit conditions in the economy which can be controlled by manipulating the cost of intermediation by the regulatory authorities.

On the other hand, both monetary and macroprudential policy impact inflation and other nominal variables. Inflation inherits the persistence in the bubble. Combining the Taylor rule under equation 2.23 and equation 2.20, the following law of motion of inflation can be derived

$$\hat{\pi}_t = [(\phi^q - \frac{\gamma_{2B}^E + \frac{\gamma_{1B}^E}{\bar{R}^d}}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)}) \bar{R}^d \hat{B}_t + (\phi^q - \frac{\gamma_{2B}^E}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)})(1 - \bar{R}^d) \hat{u}_t + \frac{\gamma_{1b}^E + \gamma_{2R}^E}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)} \hat{b}_t] \quad (2.29)$$

Equation 2.29 predicts that for a given level of  $\phi^b$ , a positive systematic response of the interest rate to aggregate bubble is desirable ( $\phi_q > 0$ ) from the viewpoint of inflation stabilization. This claim is substantiated once we look at the variance of inflation given as

$$\begin{aligned} var(\hat{\pi}_t) = & [(\phi^q - \frac{\gamma_{2B}^E + \frac{\gamma_{1B}^E}{\bar{R}^d}}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)})^2 (\bar{R}^d)^2 var(\hat{B}_t) \\ & + (\phi^q - \frac{\gamma_{2B}^E}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)})^2 (1 - \bar{R}^d)^2 (\sigma_u)^2 + (\frac{\gamma_{1b}^E + \gamma_{2R}^E}{(\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E)})^2 var(\hat{b}_t)] \end{aligned} \quad (2.30)$$

which is minimized at

$$argmin(V(\pi_t))|_{\phi_q} = \phi_q^* = (\frac{1}{\gamma_{2R}^E \frac{\bar{R}^d}{\bar{R}^b} - \gamma_{2B}^E}) [\gamma_{2B}^E + \bar{R}^d \gamma_{1B}^E] \frac{var(\hat{B}_t)}{var(\hat{q}_t^B)}$$

### 2.6.1 Sticky Price Equilibrium

Combining equations 2.14-2.17 and equation 2.24 and 2.25, goods market clearing condition can be written as

$$\begin{aligned}
2\bar{D}\hat{D}_t + (2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E})\bar{B}\hat{B}_t + \bar{B}[\frac{(1 - \bar{R}^d)}{\beta^{NE}\bar{R}^d} + \frac{(1 - \bar{R}^b)}{\beta^E\bar{R}^b}]\hat{u}_t \\
+ [\bar{B}(\frac{1}{\beta^{NE}\bar{R}^d} + \frac{\bar{R}^d}{\beta^E(\bar{R}^b)^2}) + \bar{b}(\frac{1}{\beta^{NE}} - \frac{\bar{R}^d}{\beta^E\bar{R}}) - (\bar{C}_1^{NE} + \frac{\bar{R}^d}{\bar{R}^b}\bar{C}_1^E)]\hat{r}_t^d \\
+ \bar{b}(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E})\hat{b}_t - \phi^b\bar{b}\hat{b}_{t-1} + \phi^b\bar{b}\hat{b}_t = 0 \quad (2.31)
\end{aligned}$$

Taking expectations, using equation 2.22 and after rearranging the above equation leads to

$$E_{t-1}(\hat{r}_t^d) = (2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E})\frac{\bar{B}}{V}E_{t-1}(\hat{B}_t) + \frac{\bar{b}}{V}(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b)E_{t-1}(\hat{b}_t) - \phi^b\bar{b}\hat{b}_{t-1} \quad (2.32)$$

where  $V = [C_1^{NE} - \frac{1}{\beta^E}(\bar{b} + \frac{\bar{B}}{\bar{R}^d}) + \frac{\bar{C}_1^E}{(1 + \frac{\phi^b}{\bar{R}^d})} + \frac{\bar{R}^d}{\beta^E\bar{R}^b}(1 - \frac{\bar{B}}{1 + \frac{\phi^b}{\bar{R}^d}})]$ . With the assumption under equation 22, and with pre-determination of prices ( $E_{t-1}(\pi_t)$ ), combining the previous equation with the interest rate rule, the closed form solution for the law of motion of the bubble can be written as.

$$\begin{aligned}
\hat{B}_t = \Lambda\hat{B}_{t-1} + (1 + \phi^q)(1 - \bar{R}^d)\hat{u}_{t-1} + (\phi_q - \frac{B}{VR^d}(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E}))\bar{R}^d\zeta_{t-1} \\
- \frac{\bar{b}\phi^b}{V}\hat{b}_{t-2} + \frac{\bar{b}}{V}(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b)E_{t-2}(\hat{b}_{t-1}) + \zeta_t \quad (2.33)
\end{aligned}$$

where  $\Lambda = [R_d + \frac{B}{V}(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E})] \in (0, 1)$  is the autoregressive coefficient that measures the persistence of bubble fluctuations and is independent of monetary policy parameters. Although the persistence term is independent of monetary policy parameters, as also in Galí (2014) choice of  $\phi_q$  may influence bubble's overall size and volatility. Macro-prudential policy parameters, on the other hand, influence the persistence of the bubbles through the term  $V$  in addition to its size

and volatility as is evident from the following anticipated component of the bubble  $E_{t-1}(\hat{B}_t)$  which evolves as an AR(1) process,

$$E_{t-1}(\hat{B}_t) = \Lambda \hat{B}_{t-1} + (1 + \phi^q)(1 - \bar{R}^d)\hat{u}_{t-1} + (\phi_q - \frac{B}{VR^d}(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E}))\bar{R}^d\zeta_{t-1} - \frac{\bar{b}\phi^b}{V}\hat{b}_{t-2} + \frac{\bar{b}}{V}(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b)(\hat{b}_{t-1}) \quad (2.34)$$

In other words, in the presence of nominal rigidities, monetary policy affects the size of the bubble and the allocation of consumption across cohorts and hence welfare by influencing the real interest rate. An analysis of volatility of bubble shows that a leaning against the wind monetary policy ( $\phi_q > 0$ ) generates a larger volatility in the bubble than a policy of neglect ( $\phi_q = 0$ ) (Figure:2.1). Given a finite value of  $\phi^b$ , bubble volatility is minimised at  $\phi_q = -1$ . These conditions would completely stabilize the anticipated component of the bubble. Hence, the results of the model with financial frictions nests Gali(2014)'s remarks. Stabilization of the bubble requires that interest rate be lowered in response to positive innovations in existing or new bubbles.

$$Var(\hat{B}_t) = \frac{1}{(1 - \Lambda^2)}[(1 + \phi_q^2)\sigma_\varepsilon^2 + (\frac{\bar{b}}{V}(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b))^2Var(\hat{b}_{t-1}) + (\frac{\bar{b}\phi^b}{V})^2Var(\hat{b}_{t-2})] \quad (2.35)$$

But the dynamics of macroprudential policy including its impact on credit, interest rate and bubble is much more convoluted. And an ideal way to trace and understand these complex dynamics would be to plot the bubble volatility against macro-prudential parameter ( $\phi^b$ ). Two important observations emerge from these figures. One, the relationship between bubble volatility and macro-prudential parameters is non-monotonic. Bubble volatility initially declines when  $\phi^b$  lies between 0 and a threshold value,  $\bar{\phi}^b$ , and then increases monotonically. Two, as the interest rate response of monetary policy to the bubble gets stronger, it necessitates a stronger macro-prudential policy response to absorb the excess volatility generated by strong monetary policy on bubble volatility (Figure:2.2). In other words, performance of macro-prudential policy supports monetary policy.

These dynamics can be explained within the model. Lets consider the first observation, non-monotonicity of the relationship between bubble volatility and macroprudential parameter. It is

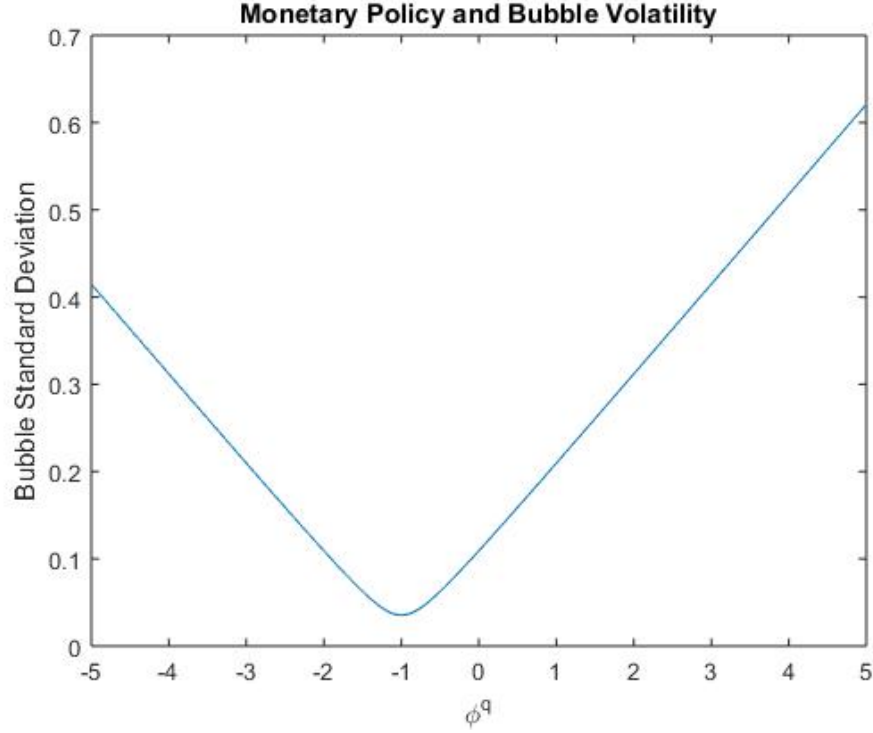


Figure 2.1: Monetary Policy and Bubble Volatility

easy to see from equation 2.35 that volatility in credit has a positive cumulative impact on volatility of bubbles. When  $\phi^b$  is below a threshold value  $\tilde{\phi}^b$ , interest rate spreads are contained which implies that the factor  $V$  may actually rise in value with small increases in  $\phi^b$  leading to a dampening impact of current bubble shocks on future bubbles. The volatility of bubbles actually declines at small levels of  $\phi^b$  as the rise in  $V$  offsets the positive cumulative impact of volatile credit. But for large increases in  $\phi^b$ , leading to large interest rate spreads,  $V$  may actually decline raising the volatility of bubbles.<sup>2</sup>

But as  $\phi^b$  increases beyond  $\tilde{\phi}^b$ , increases in  $\phi^b$  leads to higher interest rate spreads. The ensuing rise in lending rates poses a decision problem for the entrepreneurs who has to now choose between higher consumption today with higher borrowing and lower consumption in old age due to increased debt burden on account of higher interest rate. In other words, while monetary policy affects the size of the bubble and the incentives for intertemporal allocation of consumption of both entrepreneurs and non-entrepreneurs by influencing the real deposit rate, macroprudential policy

<sup>2</sup>Baseline settings assume  $m = 1.2$ ,  $B = 0.001$ ,  $\text{var}(\hat{b}_t) = 0.01$ ,  $\sigma_\varepsilon = 0.01$

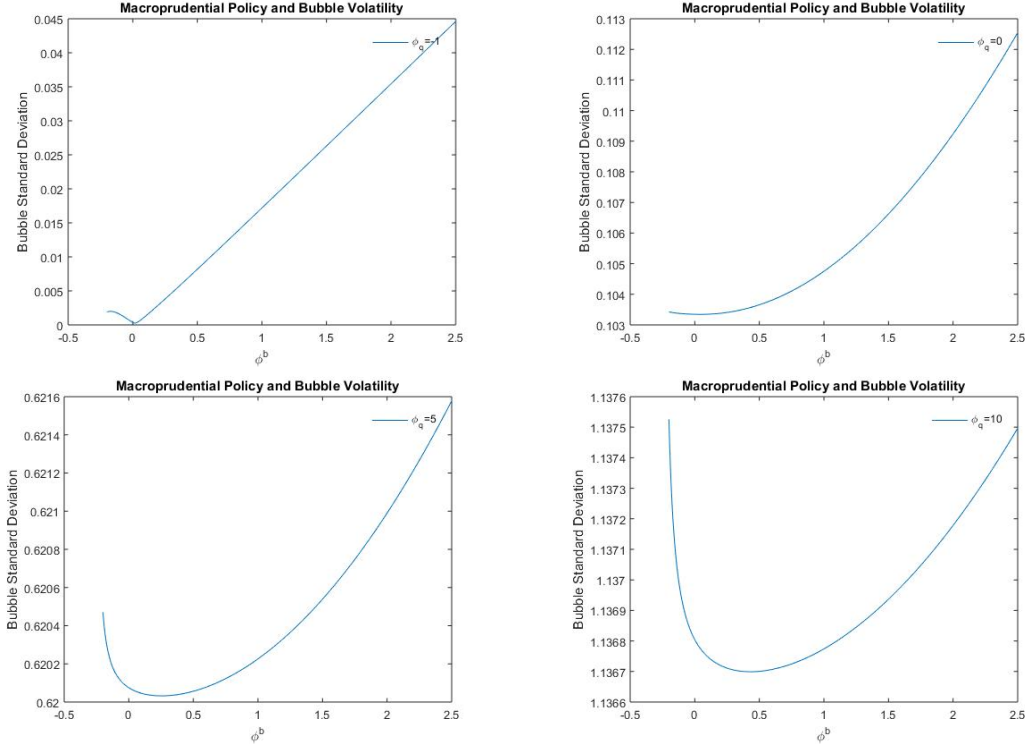


Figure 2.2: Macro-prudential Policy and Bubble Volatility

affects the intertemporal consumption allocation decision of only the entrepreneurs through the lending rate channel affecting their welfare.

In sum, the bubble is under a twin effect, monetary policy which necessitates a decreasing interest rate response to the bubble and macroprudential policy which requires an increasing response to the bubble and works through the lending rate channel. While a necessary condition for minimisation of bubble volatility is to set  $\phi_q = -1$  or passive monetary policy, an active macroprudential policy parameter,  $\phi^b \leq \bar{\phi}^b$  minimises bubble volatility given a finite value of  $\phi_q$ . Further, macroprudential policies influence the size and volatility of the bubble both under flexible (Equation 2.28) as well as sticky prices (Equation 2.33).

Table 2.1 and Figure 2.2 display the bubble standard deviation against the macroprudential parameter under changing monetary policy stance. As the interest rate response to the bubble strengthens, macroprudential parameter that minimises the bubble volatility also increases so as to absorb the excess volatility created by monetary policy.



Table 2.1: **Macro-prudential Policy Coefficient** -  $(\phi^b)^* = \text{argmin}(\text{Var}(\hat{B}_t))$

<i>Monetary Policy Stance</i>	<i>Monetary Policy Coef.</i>	<i>Macro-prudential Policy Coef.</i>	<i>Bubble Std.Dev</i>
Passive	-1	0.0327	0.003
Benign Neglect	0	0.1030	0.1033
Very Active	5	0.4601	0.6200
Very Very Active	10	0.8876	1.1367

Under sticky prices, equilibrium inflation in the economy is given as

$$\begin{aligned}
\pi_t = & \Lambda \pi_{t-1} + \left(\frac{1}{\phi_\pi}\right) \left(\frac{\bar{b}}{V}\right) \left(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b\right) (E_{t-1}(\hat{b}_t) - E_{t-2}(\hat{b}_{t-1})) \\
& - \left(\frac{1}{\phi_\pi}\right) \left(\frac{\phi^b \bar{b}}{V}\right) (\hat{b}_{t-1} - (1 + \phi^q) \bar{R}^d \hat{b}_{t-2}) + \left(\frac{1}{\phi_\pi}\right) \left(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E}\right) \left(\frac{\bar{B} \bar{b}}{V^2}\right) \left(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b\right) (\hat{b}_{t-1} - E_{t-2}(\hat{b}_{t-1})) \\
& - \left(\frac{1}{\phi_\pi}\right) (\phi^q \bar{R}^d) \left(\frac{\bar{b}}{V}\right) \left(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b\right) \hat{b}_{t-1} - \left(\frac{1}{\phi_\pi}\right) \left(\phi^q - \left(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E}\right) \frac{\bar{B}}{V \bar{R}^d}\right) \bar{R}^d (1 + \phi^q) \varepsilon_{t-1}
\end{aligned} \tag{2.36}$$

Inflation inherits the persistence in bubbles but unlike Gali (2014), past credit growth and errors in expected credit growth is contributing to inflation. The only feasible strategy before the central bank to stabilise inflation under these circumstances is to respond very strongly to inflation by setting  $\phi_\pi$  arbitrarily large, for any finite  $\phi_q$  and  $\phi^b$ . Setting  $\phi^q = -1$  may minimise variance of the bubble, but it is not sufficient to stabilise inflation.

## 2.7 Optimal Policy Mix

I take as welfare criterion the weighted unconditional mean of savers and borrowers in the economy, where  $w$  is the weight on the savers (Quint and Rabanal (2014)). Around the steady state, the mean can be approximated up to the second order as

$$\begin{aligned}
& wE[\log(C_{1,t}^{NE}) + \beta^{NE}\log(C_{2,t+1}^{NE})] + (1-w)E[\log(C_{1,t}^E) + \beta^E\log(C_{2,t+1}^E)] \\
& \cong wE[\log(C_{1,t}^{NE}) + \beta^{NE}\log(C_{2,t+1}^{NE}) - 0.5(\text{var}(\hat{C}_{1,t}^{NE}) + \beta^{NE}\text{var}(\hat{C}_{2,t}^{NE}))] \\
& + (1-w)E[\log(C_{1,t}^E) + \beta^E\log(C_{2,t+1}^E) - 0.5(\text{var}(\hat{C}_{1,t}^E) + \beta^E\text{var}(\hat{C}_{2,t}^E))]
\end{aligned} \tag{2.37}$$

Given, the goods market clearing condition  $C_{1,t}^{NE} + C_{2,t}^{NE} + C_{1,t}^E + C_{2,t}^E = 1$ , welfare maximization amounts to minimizing  $w\text{var}(C_{2,t}^{NE}) + (1-w)\text{var}(C_{2,t}^E) + (\phi^b)^2\text{var}(\hat{b}_t)$ . Substituting the values of  $C_{2,t}^{NE}$  and  $C_{2,t}^E$  from equation 2.17 and 2.19 into the required minimisation, the following expression is derived

$$\begin{aligned}
& 0.25\mathscr{W}[(\phi^q - (2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E})\frac{\bar{B}}{V\bar{R}^d})(\bar{R}^d V \sigma_\zeta)^2 + (\phi^q)^2(1 - \bar{R}^d)^2 V^2(\sigma_u)^2 + b^2(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b)^2\text{var}(\hat{b}_t) \\
& + (\bar{B})^2(\frac{(1 - \bar{R}^d)}{\beta^{NE}\bar{R}^d} + (\frac{(1 - \bar{R}^b)}{\beta^E\bar{R}^b})^2(\sigma_u)^2] + \mathscr{W}(\bar{B})^2[\frac{(1 + \phi^q)^2(\sigma_\varepsilon)^2}{(1 - \chi^2)} + (\frac{b}{V})^2(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b)^2\frac{\text{var}(\hat{b}_{t-1})}{1 - \chi^2} + \frac{\text{var}(\hat{b}_{t-2})}{1 - \chi^2}] \\
& + \mathscr{W}(\bar{R}^d\bar{b})^2[(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E})(\frac{\bar{B}}{V})^2\text{var}(E_{t-1}(\hat{B}_t)) + (\frac{\bar{b}}{V})^2(\frac{1}{\beta^{NE}} - \frac{1}{\beta^E} + \phi^b)^2\text{var}(E_{t-1}(\hat{b}_t)) + (\frac{\phi^b\bar{b}}{V})^2\text{var}(\hat{b}_{t-1}) + (\phi^q)^2(\sigma_\varepsilon)^2] \\
& + [w(\frac{\bar{R}^d\bar{b}}{C_2^{NE}})^2 + (1-w)(\frac{\bar{R}^b\bar{b}}{C_2^E})^2 + (\phi^b)^2]\hat{b}_t \tag{2.38}
\end{aligned}$$

where  $\mathscr{W} = [w(\frac{1}{C_2^{NE}})^2 + (1-w)(\frac{1}{C_2^E})^2]$ . Prior to analysing the implications on welfare, it is important to undertake a post mortem of the above equation. Minimisation of volatility of dividends with respect to  $\phi^q$  requires the central bank to set

$$\phi_q^* = \frac{(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E})\bar{B}\bar{R}^d}{V}(\frac{\sigma_\zeta}{\sigma_u})^2$$

This requires the central bank to adjust interest rate upward in response to positive bubble shocks to stabilize current aggregate demand, a policy which is in conflict with the policy of minimisation of bubble volatility which requires a downward adjustment of interest rates in response to the bubble. Contrary to this, the setting of macro-prudential policy parameter creates no dilemma for the authorities, at least below the threshold level of macroprudential policy parameter. As

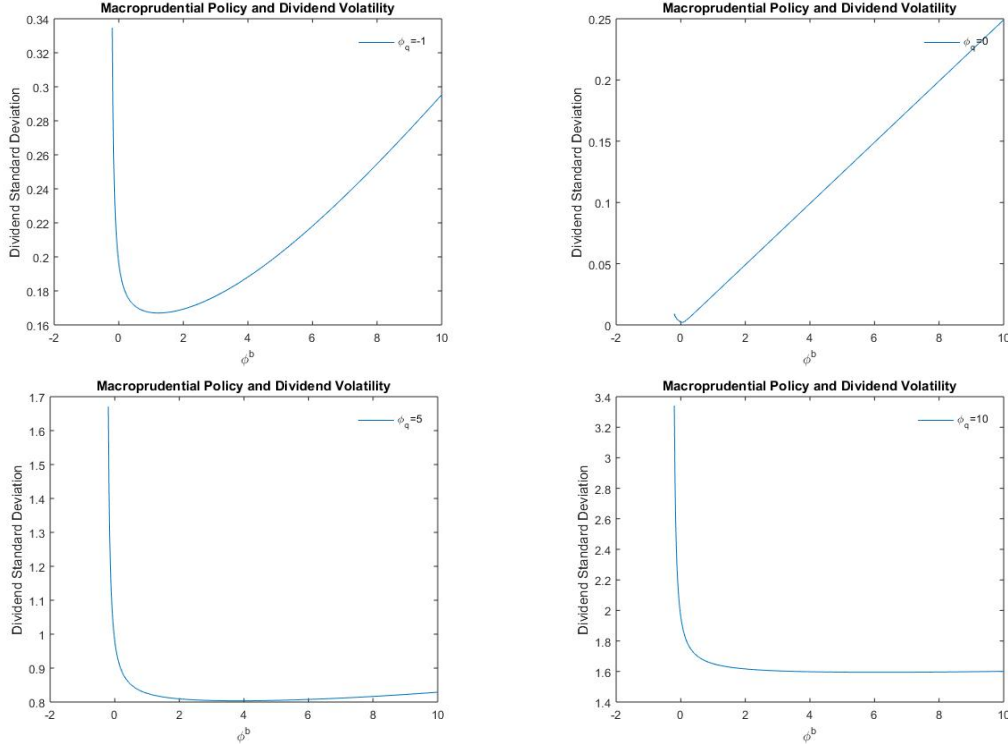


Figure 2.3: Macro-prudential Policy and Dividend Volatility

demonstrated in the last section, minimisation of bubble volatility requires setting of an active macro-prudential parameter below a certain bound but the optimizing value of this parameter must rise with the increasing monetary policy response to the bubble. Stabilization of dividends also requires an increasing macroprudential response to the bubble as is evident from Figure 2.3. As both policies point in the same direction, the welfare maximizing  $\phi^b$  marries the twin policies of stabilization of dividends and stabilization of the bubble, at least until the macroprudential parameter is below the threshold.

Figure 4 shows the expected welfare loss as a function of  $\phi_q$  and  $\phi^b$ , respectively under model's baseline parameter settings. Differentiating equation 2.28 with respect to  $\phi_q$  yields the welfare maximizing optimal bubble coefficient  $\phi_q^{**}$

$$\phi_q^{**} = \frac{(0.25(2 + \frac{1}{\beta^{NE}} + \frac{1}{\beta^E})\bar{B}\bar{R}^d V(\frac{\sigma_\epsilon}{\sigma_\epsilon})^2 - \frac{B^2}{1-\chi^2})}{(0.25V^2(\sigma_\epsilon)^2 + ((\bar{R}^d \bar{b})^2) + \frac{B^2}{1-\chi^2})} \quad (2.39)$$

Table 2.2: **Optimal Macro-prudential Policy Coefficient**

<i>Monetary Policy Stance</i>	<i>Monetary Policy Coef.</i>	<i>Macro-prudential Policy Coef.</i>
Passive	-1	0.4
Active	5	1.067
Very Active	10	1.267

The optimal coefficient is largely monotonically decreasing in the size of the bubble as is evident from Figure 5. As the steady state size of the bubble approaches zero, the optimal coefficient converges to zero. But as the bubble approaches its maximum value consistent with the stationarity such that  $\Lambda \rightarrow 1$ , then  $\lim_{B \rightarrow B^*} \phi_q^{**} = -1$ , which asymptotically tends to a negative number when the gross interest rate is greater than one. Hence, given a large bubble consistent with steady state, it is optimal for central bank to lower interest rates in response to a rise in the size of the bubble.

The optimal macro-prudential coefficient is difficult to estimate analytically as the differentiation of equation 41 with respect to  $\phi^b$  yields an implicit function in  $\phi^b$ . However, an investigation of the plot of welfare losses vis-a-vis  $\phi^b$  shows that the minimum of the loss function is attained between 0 and 2.

## 2.8 Empirical Validation

The theoretical results of the previous section are empirically validated using structural and sign restrictions VAR to assess the macroprudential role of loan loss provisions on business cycles and asset prices in the US. Loan loss provisions and supervisory capital requirements based upon the level of risk in a bank's financial positions are directly linked (Angklomkiew et al (2009)). The agreement on the framework for capital adequacy reached in July 1988 by the Basel Committee on Banking Supervision with the endorsement of central bank governors of Group of Ten countries made general provisions and loan loss reserves a part of Tier 2 capital or supplemental capital.

Basel III continued with this arrangement and allowed for inclusion of provisions in the Tier 2 capital. In 2013, the Federal Deposit Insurance Corporation, Federal Regulatory Board (FRB) and Office of the Controller of currency (OCC) issued guidelines for insured depository institutions in the US that align with Basel III capital standards. Under these guidelines, Tier 2 capital includes the allowance for loan and lease losses upto 1.25 per cent of risk-weighted assets, qualifying preferred stock, subordinated debt and sundry other assets in the US. Thus the contribution of loan loss reserves as a macroprudential policy tool, though underestimated in empirical studies in the past, can no longer be overlooked in the post global crisis economic environment (Zilberman and Tayler (2015)).

However, a major issue with designing macro-prudential instruments is the alleged procyclicality of these instruments. Downturns in business cycles are associated with deterioration of bank asset quality and hence increased risk exposure coupled with rise in capital requirements at a time when raising fresh capital from the market is difficult and banks are forced to downsize their lending. Similarly, during cyclical downturns, with heightened likelihood of loan defaults, banks are likely to respond by hiking provision requirements, further dampening the credit cycle and exacerbating the downward cycle. While low interest rates and increasing house prices have contributed to lower provisions, structural factors like improvement in risk management techniques and availability of novel instruments like securitisation which enable banks to offload a part of their credit risk have also contributed in moderating provision levels in the banking system (ECB, 2004). An adjacent view by Borio (2001) and Lowe (2002) reinforce this argument. They argue that increased lending is associated with less critical assessment of creditworthiness which in turn induces building up of risks and financial imbalances during upswings raising the probability of a downturn. With this failed experience in the background, global policymakers are currently experimenting with forward looking provisions. Along with the impact of provisions shock on business cycles, this paper also looks at the impact of forward looking or dynamic provisions on various variables.

I set up a simple SVAR model under two different specifications and check the robustness of the results by comparing it with sign restrictions VAR using data for the period 1985 Q1 to 2016

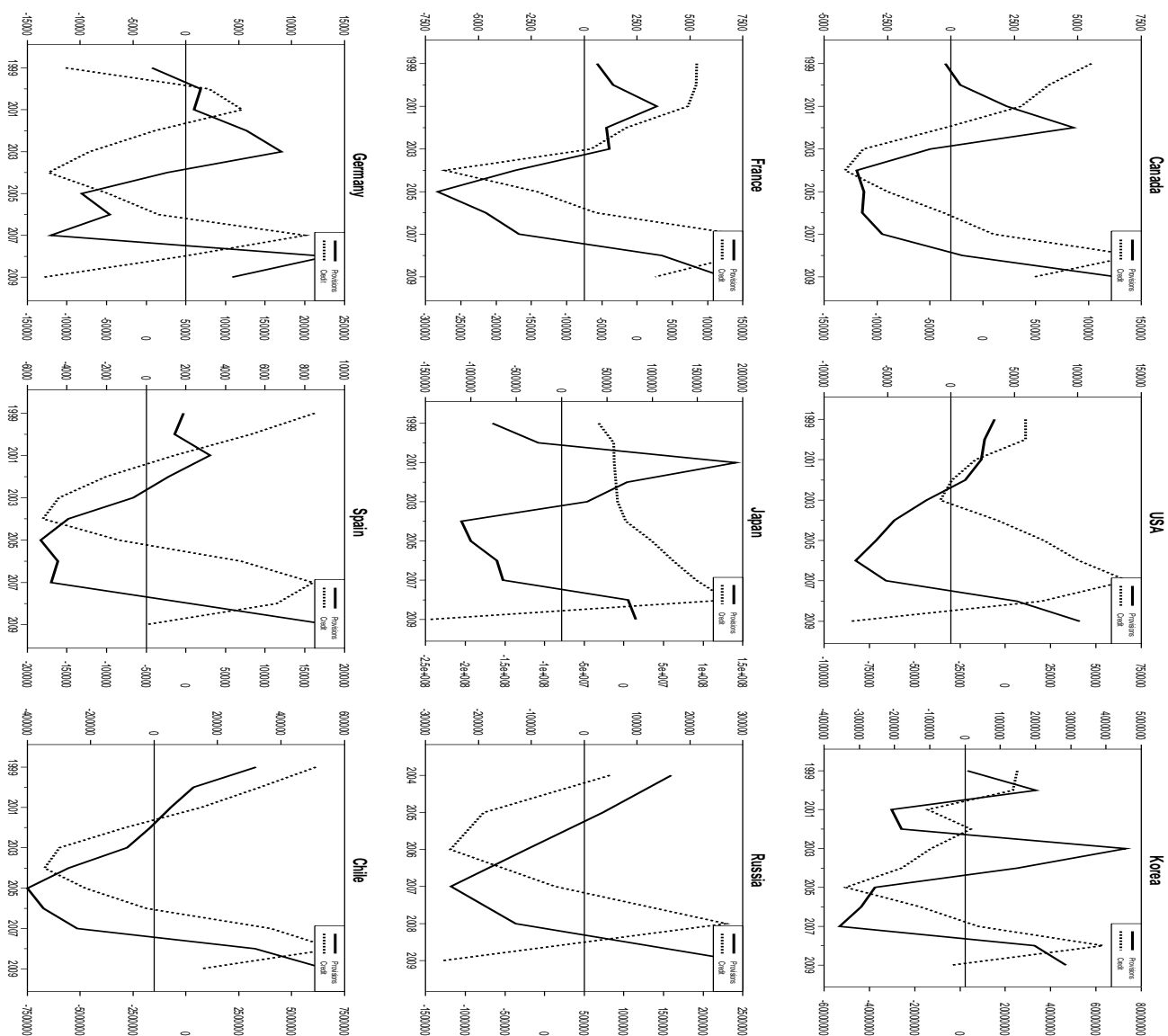


Figure 2.4: Cross Country Trends in Loan Loss Provisions

Q4 for the US economy. Data on US GDP (y), GDP deflator (p), prime loan rate of banks (r), S and P 500 stock price index (s), loan loss reserves to total loans (l) and commercial and industrial loans (c) has been sourced from Federal Reserve Bank of St. Louis database. Commodity prices (c) have been downloaded from the World Bank database and S and P 500 dividends (d) from Robert Shiller's webpage. The first specification is akin to the recursive ordering of variables in Gali and Gambetti (2015) with the addition of loan loss provisions and interest rate spread. The identification strategy in the second specification derives from the theoretical model detailed above. We check the robustness of the results by re-estimating the model with pre crisis data from 1985:1-2007:4.

### **2.8.1 Theory on Loan Loss Provisions**

Loan loss provisions have, hitherto, been governed by International Accounting Standards (IAS 39) which require banks to adopt an Incurred Loss Approach of loan loss provisioning whereby provisions are made only if losses are actually incurred. This gives prominence only to the specific provisions component of provisions which depend on expected losses on loans that have been identified as impaired or non-performing. General provisions category of loan loss provisions which depend on expected losses that cannot be supported by loan specific documentation and hence are more forward looking receive much less importance under the prevailing accounting system (Bouvatier and Lepetit (2012); Agenor and Zilberman (2013)). In other words, under the incurred loss model, loan losses are recognised quite late in the credit cycle and hence this component of loan loss provisions is susceptible to procyclicality (BIS; 2009).

To mitigate procyclicality, post crisis, this accounting system is proposed to be amended by shifting to an expected loss approach. A more forward looking provisioning system, also known as dynamic or statistical provisioning system is proposed as an alternative institutional arrangement to cover expected loan losses. Under this approach, banks predict the latent risks over the business cycle of the loan portfolio. Statistical provisions are defined as the estimated latent losses net of specific provisions. During upswings in business cycle, specific provisions are low and hence

banks accumulate a coffer of statistical provisions which can be used during downturns to handle contemporaneous problem loans. Thus statistical provisions are used to offset countercyclical evolution of specific provisions and total loan loss provisions are smoothed overtime (Bouvatier and Lepetit; 2012).

The literature on loan loss provisioning, empirical and theoretical, have largely revolved around the impact of loan loss provisioning on business cycles (Pool et al (2014), Agenor and Zilberman (2015), Zilberman and Taylor (2015)), signalling effect of loan loss provisioning announcements (Blose (2001), Docking et al (1997), Kanagaretnam (2005)) and the procyclicality of loan loss provisioning. Using panel vector autoregression, Pool et al (2014) find that increased loan loss provisioning is an indicator of increasing credit risk of the banking system which leads to lower bank lending and economic activity. The literature on loan loss provisions exhibit that loan loss provisions can be decomposed into discretionary and non-discretionary components. While, the discretionary component refers to loan loss provisions made for managerial objectives such as income smoothing, capital management or signalling, non-discretionary component represents loan loss provisions made to cover expected credit losses (Whalen, 1994; Beaver and Engel, 1996; Hasan and Wall, 2004; Bouvatier and Lepetit, 2008). The non-discretionary component can be further decomposed to separate the backward looking components which relate to non-performing loans or identified problem loans and forward looking components represented by risk of default emerging from unidentified loan losses. A number of studies have found that non-discretionary loan loss provisioning under backward looking provisioning amplify procyclicality of bank lending (Bouvatier and Lepetit;2014). Agenor and Zilberman (2015) use a dsge model with credit market imperfections to show that a dynamic provisioning system combined with credit gap-augmented Taylor rule can mitigate real and financial fluctuations. They find that standard Taylor rules combined with dynamic provisions score over credit-gap augmented Taylor rules. Zilberman and Tayler (2015) study the optimal monetary policy response in a dsge model with loan loss provisioning rules and nominal rigidities. They find that a backward looking provisioning regime induces financial accelerator mechanisms resulting in price, financial and macroeconomic instability. Dynamic provisioning, on



the other hand, attenuate welfare losses and also moderate the anti-inflationary stance of monetary policy. They find that a standard Taylor rule coupled with dynamic provisioning is an optimal policy response to financial shocks. Blose (2001) studied the market reaction to press announcements of loan loss provisioning in the banking industry. He established that informational asymmetry regarding asset value and costs associated with capital adequacy regulation generate negative reactions. He also found that type of reaction depends on type of asset being provisioned. While announcements regarding provisioning of foreign debt induce positive market reactions, announcements of provisioning of real estate loans and other types of debt lead to negative market reactions. Docking et al (1997) also underscored the negative and statistically significant signalling impact of announcement effects of bank loan loss reserves. Kanagaretnam et al (2005) document that bank managers use their discretion in estimating loan loss provisions to communicate private information about their bank's future prospects depending on different incentives. They established that these announcements have significant contagion effects on non-announcing regional banks. Propensity to signal private information vary systematically with bank size, earnings variability, future investment opportunities and degree of income smoothing. A number of studies look at the procyclicality of the loan loss provisioning system (Laeven and Majnoni (2001), Bouvatier and Lepetit (2012a), (2012b)). Bouvatier and Lepetit (2012a) find that backward looking provisioning system aggravates the cyclicity of bank lending, with the effect being relatively stronger for emerging economies. In a similar theoretical study of the issue, Bouvatier and Lepetit (2012b) establish that while a backward looking provisioning system amplifies the procyclicality of loan market fluctuations, a forward looking or dynamic system of provisioning smoothes the evolution of total loan loss provisions, eradicating procyclicality. Bushman and Williams (2012) point out a trade-off between reduced procyclicality and loss of transparency leading to dampening of market discipline and imprudent risk taking in forward looking provisioning system. However, none of the above studies draw attention to the impact of provisions on asset bubbles and this empirical study fills up this gap substantiating the theoretical results from the overlapping generations model set out above. The literature on loan loss provisioning is at an early stage and to the best of our knowledge

this is the first paper that looks at the joint impact of monetary policy and loan loss provisioning on asset bubbles. Further, to accomplish these goals, I follow a sign restrictions approach which is also an added attraction of this paper. Unlike the monetary policy theory, the theory of macroprudential policy is pre-mature. Hence, sign restrictions approach is clearly a useful procedure in the assessment of macroprudential policy shocks as there is relatively little theoretical guidance (as compared to the volume of work on monetary policy) on how such a policy reacts to or is reacted to.

## 2.8.2 Identification Strategy

### 2.8.2.1 Recursive VAR

#### 1. (6 variable VAR)

Consider the following summative reduced form VAR model

$$x_t = P_1 x_{t-1} + e_t \quad (2.40)$$

where  $x_t$  is  $n \times 1$  vector of variables and  $\Sigma_e = E_t(e_t e_t')$ . Let  $Q_0$  be a cholesky factor of  $\Sigma_e$  such that  $\Sigma_e = Q_0 Q_0'$ . Pre-multiplying (1) by  $Q_0$ , we have the structural representation of the model given as

$$Q_0 x_t = Q_1 x_{t-1} + \varepsilon_t \quad (2.41)$$

implying that structural shocks are linear combinations of VAR errors,  $Q_0 e_t = \varepsilon_t$  and  $E(\varepsilon_t \varepsilon_t') = \Sigma_\varepsilon$ , where  $\Sigma_\varepsilon$  is a positive definite matrix. Identification of structural shocks thus depends on the construction of an appropriate set of weights ( $Q_0$ ) on  $\hat{e}_t$  (Fry and Pagan (2011)). The recursive approach restricts  $Q_0$  matrix to a lower triangular matrix with a unit diagonal which implies the decomposition of variance-covariance matrix  $\Sigma_e = Q_0^{-1} \Sigma_\varepsilon (Q_0^{-1})'$ . In the first part of the empirical exercise, the choice of variables and identification strategy follows Christiano et al (1998). As Christiano et al (1998) explains the vector of endogenous variables

can be partitioned into three blocks:  $z_t$  is the set of policy instruments;  $x_{1,t}$  is the set of those variables whose contemporaneous values appear in the information set of the policymaker at time  $t$  and  $x_{2,t}$  is the set of variables that appear with a lag in the information set. In other words, recursiveness assumption implies that time  $t$  variables that appear in the information set of the policy maker do not respond to time  $t$  realizations of the policy shock. Instead, they respond with a lag to the policy shock. Define  $x_t = [y_t, div_t, p_t, p_t^{com}, policyvariable, s_t]$  where  $y_t$  is log (output),  $div_t$  is log (dividends),  $p_t$  log (prices),  $p_t^{com}$  is log (commodity prices), the policy variable is either  $i_t$ , the short term nominal interest rate or  $lp_t$ , the log (loan loss provisions) and  $s_t$  is the log (stock price index). The policy block in this model consists of  $z_t = [i_t, lp_t]$ ,  $x_{1,t} = [y_t, div_t, p_t, p_t^{com}]$  whose contemporaneous values appear in the information set of the policymaker at time  $t$  and  $x_{2,t} = [s_t]$  which appear with a lag in the information set.

The first specification is similar to Gali and Gambetti (2015) with interest preceding stock prices. This is the standard Taylor rule which can be viewed as incorporating a pre-emptive response to bubbles with a view to mitigating future risk of inflation since effects of asset price fluctuations are included in the changes in the output gap guiding short term nominal interest rate (Bernanke and Gertler (1999), Shirutsuka (2000)). I also consider another specification allowing for endogenous contemporaneous response of interest rates to stock prices in line with the familiar 'leaning against the wind' policy. This amounts to interpreting the Taylor rule as directly including information about stock prices. The recursiveness assumption thus places the following zero restrictions on  $Q_0$  and the linear relationship between reduced form errors and structural errors can be expressed as under.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ -\beta_{dy} & 1 & 0 & 0 & 0 & 0 \\ -\beta_{py} & -\beta_{pd} & 1 & 0 & 0 & 0 \\ -\beta_{cy} & -\beta_{cd} & -\beta_{cp} & 1 & 0 & 0 \\ -\beta_{sy} & -\beta_{sd} & -\beta_{sp} & -\beta_{sc} & 1 & 0 \\ -\beta_{ry} & -\beta_{rd} & -\beta_{rp} & -\beta_{rc} & -\beta_{rs} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_y \\ \varepsilon_d \\ \varepsilon_p \\ \varepsilon_c \\ \varepsilon_s \\ \varepsilon_r \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_y \\ e_d \\ e_p \\ e_c \\ e_s \\ e_r \end{bmatrix}$$

The results are similar when I use either the policy rate or the lending rate. To evaluate the impact of pure provisions shock on asset prices, two identification strategies have been used. One, provisions are allowed to react to output such that provisions are ordered after output, dividends and prices in that order and stock prices are ordered last. Two, endogenous contemporaneous response of provisions to stock prices is allowed for such that stock prices respond contemporaneously to all variables except provisions, while provisions are ordered last and hence it responds contemporaneously to all variables. The recursiveness assumption thus places the following zero restrictions on  $Q_0$  and the linear relationship between reduced form errors and structural errors can be expressed as below.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ -\beta_{dy} & 1 & 0 & 0 & 0 & 0 \\ -\beta_{py} & -\beta_{pd} & 1 & 0 & 0 & 0 \\ -\beta_{cy} & -\beta_{cd} & -\beta_{cp} & 1 & 0 & 0 \\ -\beta_{sy} & -\beta_{sd} & -\beta_{sp} & -\beta_{sc} & 1 & 0 \\ -\beta_{ly} & -\beta_{ld} & -\beta_{lp} & -\beta_{lc} & -\beta_{ls} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_y \\ \varepsilon_d \\ \varepsilon_p \\ \varepsilon_c \\ \varepsilon_s \\ \varepsilon_l \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_y \\ e_d \\ e_p \\ e_c \\ e_s \\ e_l \end{bmatrix}$$

To evaluate the impact of provisions shock on asset prices in the presence of interest rates, three types of identification strategies are implemented. One, provisions are ordered after the interest rate implying that regulatory reaction function incorporates current information on

monetary policy. This represents provisions shock with a standard Taylor rule. Two, interest rate are ordered after provisions implying that central bank incorporates current information about the provisions. This represents the provisions shock with augmented Taylor rule. Both these identification strategies seem to resemble the situation where monetary policy and supervisory functions are undertaken by the same authority. In contrast, in the third strategy, it is assumed that monetary policy and provisions policy do not react to each other. This is incorporated by assuming that the coefficient on contemporaneous response of provisions to monetary policy is zero in the matrix  $Q_0$ .

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -\beta_{dy} & 1 & 0 & 0 & 0 & 0 & 0 \\ -\beta_{py} & -\beta_{pd} & 1 & 0 & 0 & 0 & 0 \\ -\beta_{cy} & -\beta_{cd} & -\beta_{cp} & 1 & 0 & 0 & 0 \\ -\beta_{ry} & -\beta_{rd} & -\beta_{rp} & -\beta_{rc} & 1 & 0 & 0 \\ -\beta_{ly} & -\beta_{ld} & -\beta_{lp} & -\beta_{lc} & 0 & 1 & 0 \\ -\beta_{sy} & -\beta_{sd} & -\beta_{sp} & -\beta_{sc} & -\beta_{sr} & \beta_{sl} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_y \\ \varepsilon_d \\ \varepsilon_p \\ \varepsilon_c \\ \varepsilon_r \\ \varepsilon_l \\ \varepsilon_s \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_y \\ e_d \\ e_p \\ e_c \\ e_r \\ e_l \\ e_s \end{bmatrix}$$

I also use interest rate spread (lending rate minus policy rate) in place of the lending rate or policy rate to estimate the model under recursive identification. According to the bank equilibrium condition interest rate spreads are determined by provisions. So spread is ordered after provisions but prior to stock prices. Next I introduce credit into this specification which reacts contemporaneously to GDP growth and dividend growth, while inflation responds concurrently to GDP growth, dividend growth and credit growth. This specification is close to the model although the recursive assumption may be construed as too restrictive which I relax in the following section.

## 2. (7-Variable VAR System)

In this section, I separate the static and dynamic components of loan loss provisions drawing on the recent accounting literature. I accomplish this by incorporating non-performing assets into the VAR and ordering it before the provisions. Non-performing loans are commemorative of identified credit losses in the financial system. So a shock to provisions after controlling for non-performing assets can be identified as a shock to dynamic provisioning. So in this case, output is ordered first, dividends second, inflation and commodity prices third and fourth, followed by NPAs and provisions and finally share prices are ordered last.

### 2.8.2.2 Non-Recursive Ordering

In the second specification, I set up a SVAR model with GDP growth, dividend growth, credit growth, inflation, loan loss provisions, credit spread and stock prices. I try to identify provisions shocks, credit shocks, technological shocks, dividends shocks, inflation shocks, interest rate spread shocks and optimism shocks by imposing zero restrictions in the contemporaneous impact matrix in accordance with the theoretical model detailed in the paper. Provisions shocks are assumed to be affecting the inflation ( $\beta_{pl}$ ), credit ( $\beta_{cl}$ ), interest rate spreads ( $\beta_{spr,l}$ ) and stock prices ( $\beta_{sl}$ ) contemporaneously. This may be deemed from the bank equilibrium condition in equation 6 where the spread of the lending rate over the policy rate is equivalent to the provisions parameter. Similarly the assumption about price inflation responding contemporaneously to provisions shocks emanates from equation 36. Negative credit or liquidity shocks is likely to put pressure on interest rate spreads ( $\beta_{spr,c}$ ).

Output responds to supply shocks only. Dividends are a barometer of good corporate performance and higher industrial output which can be associated with higher credit to entrepreneurs that enables latter to hire more labor and produce more output by model construction. Policy rate responds to inflationary shocks according to the monetary policy feedback rule assumed in the

model. Shocks in interest rate spreads is likely to affect lending rate spreads over the policy rate ( $\beta_{spr,sp}$ ) as well as stock prices concurrently ( $\beta_{ssp}$ ). Stock prices respond to all the shocks, while optimism shocks do not affect any variable except stock prices. The impact matrix now looks like

$$A_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ \beta_{dy} & 1 & 0 & 0 & 0 & 0 & 0 \\ \beta_{py} & \beta_{pd} & 1 & 0 & \beta_{pl} & 0 & 0 \\ \beta_{cy} & \beta_{cd} & \beta_{cp} & 1 & \beta_{pl} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ \beta_{spry} & \beta_{sprd} & \beta_{sprc} & \beta_{sprp} & \beta_{sprl} & 1 & 0 \\ \beta_{sy} & \beta_{sd} & \beta_{sc} & \beta_{sp} & \beta_{sl} & \beta_{ssp} & 1 \end{bmatrix}$$

## 2.8.3 Sign-Restrictions Approach

### 2.8.3.1 Mountford and Uhlig Approach

Vector autoregression is a principle tool for extracting information about the macroeconomy thanks to the seminal work of Sims (1980). However, a debatable issue in the VAR literature is to how to identify the structural shocks from the reduced form. Uhlig (1998) argues that reasonable identification is decided based on what it ought to be. For example, monetary policy shocks are identified by the fact that monetary policy contraction should raise interest rates, reduce output and prices. If a particular identification scheme meets the reasonability criteria, it is successful, otherwise it is a puzzle. Uhlig (1998) refers to this as a circular reasoning as economists are accepting results that they want to hear. Instead, Uhlig (1998) proposes a method where he prefers to keep the broader theoretical question open and allow the data to decide how a policy shock may affect the key variables in the economic system. He accomplishes this by imposing sign restrictions on impulse responses of some variables while being agnostic about others. In other words, this procedure amounts to combining minimal a priori theorizing (assumptions that enjoy broad support)

with empirical assessment of the question of interest.

Suppose solution to the companion form model in (1) is given as

$$x_t = \sum_{k=0}^{k=\infty} M(k)e_{t-k} \quad (2.42)$$

where  $M(k)$  is the  $k$ -th period impulse response of  $x_{t+k}$  to a unit change in  $e_t$  and  $M_0 = I_n$ . The corresponding structural moving average representation is given as

$$x_t = \sum_{k=0}^{k=\infty} N(k)\varepsilon(t-k) \quad (2.43)$$

with impulse responses to  $\varepsilon_t$  being  $N_j = M_j Q_0^- = M_j N_0$ .

Assume  $\hat{R}$  be the matrix containing the standard deviations of the structural shocks on the diagonal and zeros elsewhere. Then

$$\hat{e}_t = Q_0^{-1} \hat{R} \hat{R}^{-1} \hat{e}_t = \hat{U} \hat{\Gamma}_t \quad (2.44)$$

where  $\hat{\Gamma}_t = \hat{R}^{-1} \hat{e}_t$  are the rescaled structural shocks possessing unit variance. Let  $S$  be an orthonormal matrix such that  $SS' = S'S = I_n$ , then we can express a new set of structural shocks as combination of existing shocks such as  $\hat{\gamma}_t^* = S\hat{\gamma}_t$ .

Following from equation (5) above, we can now express the reduced form VAR errors as

$$\begin{aligned} \hat{e}_t &= \hat{U} \hat{\gamma}_t \\ &= \hat{U} S' S \hat{\gamma}_t \\ &= \hat{U}^* \hat{\gamma}_t^* \end{aligned} \quad (2.45)$$

and  $Cov(\hat{\gamma}_t^* \hat{\gamma}_t^*) = S Cov(\hat{\gamma}_t \hat{\gamma}_t) S' = I_n$ . In other words, we have found a new set of shocks  $\hat{\gamma}_t^*$  that have the same covariance matrix as  $\hat{\gamma}_t$  but which will have a different impact ( $U^*$ ) upon  $\hat{e}_t$  and hence the variable  $x_t$ .

Now pre-multiplying equation (1) by  $\hat{R} \hat{R}^{-1}$ , we obtain the rescaled structural VAR representation



$$\begin{aligned}
x_t &= Q_0^{-1} \hat{R} \hat{R}^{-1} \hat{\varepsilon}_t M_0 + Q_0^{-1} \hat{R} \hat{R}^{-1} \varepsilon_{t-1} M_1 + \dots \\
&= \hat{U} \hat{\gamma}_t M_0 + \hat{U} \hat{\gamma}_{t-1} M_1 + \dots \\
&= \tilde{N}_0 \hat{\gamma}_t + \tilde{N}_1 \hat{\gamma}_{t-1} + \dots
\end{aligned} \tag{2.46}$$

But since  $\hat{\varepsilon}_t = \hat{U}^* \hat{\gamma}_t^*$ , there can be an alternative structural MA representation such that

$$\begin{aligned}
x_t &= \hat{U}^* \hat{\gamma}_t^* M_0 + \hat{U}^* \hat{\gamma}_{t-1}^* M_1 + \hat{U}^* \hat{\gamma}_{t-2}^* M_2 + \dots \\
&= N_0^* \hat{\gamma}_t^* + N_1^* \hat{\gamma}_{t-1}^* + N_2^* \hat{\gamma}_{t-2}^* + \dots \\
&= \sum_{k=0}^{\infty} N(k)^* \gamma_{t-k}^*
\end{aligned} \tag{2.47}$$

where  $N(k)^* = U(\hat{k}) S' M(k)$ . So the impulse response vector of variables to a structural shock that corresponds to the  $j$ -th element of  $\varepsilon_t$  at horizon  $k$  is the  $j$ -th column of  $N(k)^*$ , denoted by  $n^{(j)}(k)$

$$n^{(j)}(k) = U(\hat{k}) s^{(j)} M(k)$$

where  $s^{(j)}$  is the  $j$ -th column of  $S$ .

Following the penalty function approach of Mountford and Uhlig(2009), that minimises the criterion function for sign restrictions, we have

$$s^* = \arg \min \phi(s)$$

subject to  $s' s = 1$

where the criterion function  $\phi(s)$  is given as

$$\phi(s) = \sum_{i \in G_{s^+}} \sum_{k=\underline{k}}^{\bar{k}} g\left(\frac{-U_i(k) \hat{M}_i(k) s}{\sigma_i}\right) + \sum_{i \in G_{s^-}} \sum_{k=\underline{k}}^{\bar{k}} g\left(\frac{U_i(k) \hat{M}_i(k) s}{\sigma_i}\right)$$

where  $g$  is the penalty function given by  $g(u) = 100u$  if  $u \geq 0$  and  $g(u) = u$  if  $u < 0$

The computations are performed, using a Bayesian approach as detailed in Uhlig (2005) and Mountford and Uhlig (2005). A number of draws are taken from the posterior. For each draw from

the posterior of the VAR coefficients and the variance-covariance matrix, the shocks are identified using the criteria described above. Given the sample of draws for the impulse responses, confidence bands are also plotted.

### 2.8.3.2 Identification under Sign Restrictions

I distinguish between three principle shocks - business cycle shock, monetary policy shock and provisions shock. In the literature, the business cycle shock has been identified with positive sign on impulse responses of output (Uhlig and Mountford;2008, Beaudry et al;2011)(Identification TI). I also experiment with another identification strategy where I identify a business cycle shock as one that moves output as well as dividends in the same direction for four quarters following the shock (Identification TII). Per Mountford and Uhlig (2005), I define the impulse vector with respect to business cycle shock as under

**Definition 1:** *A business cycle shock impulse vector is an impulse vector  $a$ , that minimizes a criterion function  $\Phi(a)$ , which penalizes negative impulse responses of output (and dividends in Identification - TII) at horizons  $k = 0, 1, 2$ , and  $3$ .*

The sign restriction on monetary policy is unambiguously identified as a positive response of the interest rate and a negative response of the prices for a year following the shock, while being agnostic about all other variables.

**Definition 2:** *A monetary policy shock impulse vector is an impulse vector  $a$ , that minimizes a criterion function  $\Phi(a)$ , which penalizes negative impulse responses of interest rate and positive impulse response of general prices and commodity prices at horizons  $k = 0, 1, 2$ , and  $3$ .*

In our benchmark identification of shocks to loan loss provisions, I impose a sign restriction only on the impulse response of provisions such that provisions rise for four quarters after the shock (Identification SI). In another identification strategy, I eliminate the price puzzle by imposing the restriction that prices decline for four quarters after a provisions shock in line with the available results from New Keynesian DSGE models (Identification SII). We are, however, agnostic about the response of output, dividends and share prices to a provisions shock.

To identify backward provisioning, I follow a threefold identification strategy. Under Identification-BI, I impose the minimum restriction that impulse response of provisions be positive. Under Identification strategy-BII, I impose a negative sign restriction on non-performing assets and a positive restriction on provisions response. Finally, under Identification - BIII, I impose additional restriction on domestic and commodity prices such that the price responses be negative following a shock. Per Mountford and Uhlig(2005), I define the following

**Definition 3:** *A provisioning shock impulse vector is an impulse vector  $a$ , that minimizes a criterion function  $\Phi(a)$ , which penalizes negative impulse responses of provisions (and positive impulse responses of prices (Identification-SII) at horizons  $k = 0, 1, 2$ , and  $3$ .*

I use three different types of sign restrictions to identify dynamic provisioning shocks. The idea is that dynamic provisioning shocks should be characterised by a rise in loan loss provisions and a fall in NPAs to total loans which capture the change in identified credit losses. To investigate the robustness of this idea, I explore three identification schemes - (i) Under Identification-DI, I impose only one sign restriction to identify a dynamic provisioning shock that the impulse response of provisions be positive. Although, it is a minimal set of restrictions, it perfectly identifies the desired shock. (ii) Under Identification - DII, in addition to the sign restriction on provisions, I impose the sign restriction on the response of NPAs to total loans to be negative for four quarters following a provisions shock. (iii) Under Identification - DIII, I impose a positive sign restriction on provisions, negative restriction on NPAs and a positive sign restriction on impulse response of prices to a dynamic provisioning shock. The response of prices to a loan loss provisioning shock is highly circumspect. While the available literature points towards a decline in prices following a provisions shock, the recursive VAR results indicate that the prices rise following a provisions shock. Hence I think it is a good idea to check the robustness of the recursive VAR results.

**Definition 4:** *A dynamic provisioning shock impulse vector is an impulse vector  $a$ , that min-*

*imizes a criterion function  $\Phi(a)$ , which penalizes negative impulse responses of provisions (and positive impulse responses of NPAs, and NPAs and prices under Identification DII and DIII, respectively) at horizons  $k = 0, 1, 2$  and  $3$ .*

In case of provisions shock, I am agnostic about the response of output, dividends and asset prices in the seven variable case. In the eight variable case, I experiment with different identification strategies by first imposing a sign restriction on interest rates along with provisions and prices and then removing the restriction and observing the response of interest rate to a shock to provisions.

Table 2.3: **Identifying Sign Restrictions**

<i>Shocks</i>	<i>GDP</i>	<i>Dividends</i>	<i>Interest Rate</i>	<i>Provisions</i>	<i>Prices</i>	<i>Commod-Price</i>	<i>NPA</i>
<b>Technology Shock</b>							
(i)TI	+						
(ii)TII	+	+					
Monetary Policy			+		(-)	(-)	
<b>Provisions Shock</b>							
(i) SI				+			
(ii)SII				+	(-)	(-)	
<b>Dynamic Provisioning</b>							
(i)DI				+			
(ii)DII				+			(-)
(iii)DIII				+	(-)	(-)	(-)

## 2.8.4 Results

### 2.8.4.1 Monetary Policy Shock

We first test the standard specification with output, dividends, general prices, commodity prices, interest rate and share prices in that order which is also similar to the specification in Gali (2014). The results are in line with the existing literature(Figure A.4). Interest rate shock significantly reduces commodity prices and dividends after a zero impact response. Prices rise initially and significantly and decline much more gradually. Share prices respond slowly and then rise over-time significantly in response to the interest rate shock. And as explained by Gali (2014), interest rate tightening seems to be enhancing the relative size of the bubble which ends up increasing the observed asset price over time, due to its positive effect on the bubble more than offsetting the

negative impact on the fundamental component. However, with sign restrictions, although output and prices decline significantly, share prices jump upwards on impact, as compared to zero impact response under recursive VAR (Figure A.5). However, I did not find any evidence with respect to decline in share prices when I allowed for an endogenous contemporaneous response of interest rate to share prices in recursive VAR. Although it must be mentioned that I did not calibrate the relevant coefficient in the monetary policy rule according to the findings in Rigobon and Sack (2003) as Gali(2013) did.

Under sign restrictions, as opposed to the above evidence, an interest rate rule that factors in provision information, significantly raises stock prices for first two quarters, although with a standard Taylor rule (interest rate preceding provisions) the share prices decline by the 10th quarter. Under recursive VAR, however, stock prices rise significantly following an interest rate shock, both for a standard Taylor rule as well as an interest rate rule that a priori factors in provision information(Figure A.8 and Figure A.10). Also in the presence of provisions under sign restrictions approach, allowing for an endogenous contemporaneous response of interest rate to share prices significantly raises share prices following an interest rate shock.

An asset quality augmented Taylor interest rate rule significantly reduces stock prices within a quarter, although temporarily. It seems that if interest rate responds contemporaneously to expected credit losses, a tightening of interest rates may be interpreted by investors as falling financial system portending tight credit conditions in the future. In other words, both the bubble and fundamental component of stock prices may be declining under backward provisioning with augmented Taylor rule.

Under dynamic provisioning with standard Taylor rule, an interest rate shock reduces prices, dividends and output effectively but raises stock prices significantly. The rise in interest rate expands the bubble component which in turn raises the stock prices. However, under dynamic provisioning with provisions and expected credit loss augmented interest rate rule, stock prices first rise immediately and peak by the fifth quarter, and then decline, though gradually but significantly.

#### 2.8.4.2 Shock to Provisions

In the benchmark identification with provisions, a shock to provisions significantly reduces stock prices on impact. Output and dividends contract after a zero impact response, while prices rise only after a prolonged period of non-response but the rise is not statistically significant (Figure A.6). Under sign restrictions, however, all variables except dividends, prices and provisions whose impulse response is restricted to be positive, rise significantly (Figure A.7). Further, output, dividends and general prices decline significantly on impact as opposed to a zero impact response under recursive VAR. Commodity prices are sticky and rise significantly on impact and moderate only after the 8th quarter. Stock prices rise on impact and moderate only after two quarters but the decline is significant only in the medium run. The spontaneous response of output, dividends and prices capture the announcement effects of policy variables which take effect after four quarters.

Incorporating interest rates into benchmark specification which may be referred to as the provisions with standard Taylor rule (interest rate precedes provisions), a shock to provisions significantly reduces stock prices, output and dividends. Interest rates also decline after zero impact response although not significantly. Prices are sticky downwards but as opposed to the benchmark identification case with provisions, they rise quickly and significantly and do not turn to zero in the medium run (Figure 9). There is no difference in the results from augmented Taylor rule where interest rates respond contemporaneously to output, dividends, prices and provisions (Figure 10).

Taking into account spread between lending rate and policy rate in place of either the lending or policy rate, a provisions shock leads to gradual and marginal increase in spreads which is not statistically significant from zero (Figure A.12). With the inclusion of spread, output and dividends decline significantly after initial zero impact response. Following a provisions shock, prices decline permanently after an initial zero impact response. Introducing credit into the specification delays the decline in prices. Prices do not respond to provisions shock until the fourth quarter and thereafter decline significantly and then returns to zero by the 12th quarter (Figure A.13). However, in all these specifications stock prices decline significantly following a provisions shock.

### **2.8.4.3 Shock to Dynamic Provisioning**

Identifying dynamic provisioning shock amounts to fixing the systematic component of loan loss provisions. I use different identifying strategies to identify the dynamic provisioning shock. Under identification I, I find that stock prices decline on impact and the permanently following a dynamic provisioning shock. A shock to asset quality raises provisions immediately and sets them permanently higher for the next many quarters. Stock prices rise initially following an asset quality shock but then declines from the third quarter. The response of stock prices to a provisions shock remains unchanged even if I endogenize the response of provisions to stock prices as under Identification II. Under sign restrictions, DII, stock price response to a dynamic provisioning shock is ambiguous. It rises initially and declines intermittently but the response is not statistically significant from zero. However, under DIII where sign restrictions are imposed on prices and NPAs, stock prices decline significantly. The response of stock prices to a asset quality shock is akin to recursive SVAR case. With the provisions shock moderating output, interest rate and fundamental component of stock prices, tightening of provisions is construed by the stock market as a future rise in credit losses. Investors factor in those adverse expectations leading to a fall in stock prices. A dynamic provisioning shock is a leading indicator of downturn in business cycle emerging in the real sector and gradually cascading to the financial sector.

### **2.8.4.4 Binning's and Modified RWZ Approach**

Mountford and Uhlig's (2005) penalty function approach to sign restrictions VAR has been criticised on more than one occasion. Arias, Ramirez and Waggoner (2014)(henceforth ARW) argue that this approach introduces sign restrictions in addition to the ones specified in identification violating proclaimed agnosticism. Hence they tend to generate biased impulse response functions and artificially narrow confidence intervals around them. They criticize the PFA as it selects a single value of structural parameter by minimizing the loss function instead of drawing from the post war distribution of structural parameters conditional on sign and zero restrictions. ARW(2014) provide an algorithm that correctly draws from the posterior distribution of structural parameters



conditional on sign and zero restrictions. However ARW (2014) makes it clear that their objective is “neither to dispute nor challenge SVAR’s identified with sign and zero restrictions”. In fact their methodology “preserves the virtues of the pure sign restrictions approach developed by Faust (1998), Canova and Nicolo (2002), Uhlig (2005) and Rubio Ramirez et al (2010). The RWZ (2010) deserves a special mention here because of its widescale use in the subsequent work in this field. The RWZ (2010) established general rank conditions for global identification of overidentified and exactly identified models. They provided a number of efficient algorithms for small sample estimation and inference. Baumeister and Benati (2013) compute the time varying structural impact matrix by combining the procedure proposed by RWZ (2010) to impose sign restrictions with the imposition of a single zero restriction via a deterministic Givens rotation matrix. Benati (2013) combined the methodology of RWZ (2010) for imposing sign restrictions with the procedure of Gali and Gambetti (2015) to impose long run restrictions using Householder transformation in a time varying VAR context.

Binning (2013) argued that PFA method had the advantage that more draws are likely to match the sign restrictions and the ordering of shocks can be used to weight the significance of the shocks. However, he also pointed out that because of the recursive solution, results may be sensitive to the ordering of the shocks. Binning (2013) extended the Rubio-Ramirez, Waggoner and Zha (2008) (henceforth RWZ) algorithm for imposing short run and long run restrictions on exactly identified models to underidentified SVAR models. In the following section, I show that how the identification strategy mentioned in the previous section can be re-estimated using Binning’s algorithm for solving underidentified SVAR combining sign and zero restrictions.

#### **2.8.4.5 Methodology**

I try to identify six shocks - provisions shocks, dividend shocks, demand shocks, supply shocks, monetary policy shocks and news shocks. I base some of my identifying assumptions on the impulse responses obtained from Smets and Wouters (2007) and Gerali et al (2010). I use the follow-

ing two identification schemes. In the first identification scheme, I assume that dividends, inflation, GDP and interest rate spreads do not respond to a provisions shock in the short run. In the long run, provisions shock affects all the variables except GDP. However, I am agnostic about the impact of provisions shock on stock price in the short run.

On impact, a monetary policy shock reduces inflation and GDP, while I am agnostic about its impact on provisions, dividends and stock prices. In the long run, monetary policy shock affects all the variables except GDP.

Aggregate supply shock is the only shock that has a long run impact on GDP, a result that has been empirically proved by many authors. Aggregate demand shock, on the other hand, raises inflation, GDP and interest rates in the short run and all variables except GDP in the long run.

$$\begin{bmatrix} L_0 \\ L_\infty \end{bmatrix} = \begin{Bmatrix} \Delta \log(llp_0) \\ \Delta \log(div_0) \\ \pi_0 \\ \Delta \log(Y_0) \\ (i_0^{plr} - i_0^{effr}) \\ \Delta \log(sp_0) \\ \Delta \log(llp_\infty) \\ \Delta \log(div_\infty) \\ \pi_\infty \\ \Delta \log(Y_\infty) \\ (i_\infty^{plr} - i_\infty^{effr}) \\ \Delta \log(sp_\infty) \end{Bmatrix} \begin{bmatrix} +1 & \times & \times & \times & \times & \times \\ 0 & +1 & \times & \times & \times & \times \\ 0 & \times & +1 & -1 & -1 & \times \\ 0 & \times & +1 & +1 & -1 & \times \\ 0 & \times & +1 & -1 & +1 & \times \\ \times & \times & \times & \times & \times & \times \\ \times & \times & \times & \times & \times & \times \\ \times & \times & \times & \times & \times & \times \\ \times & \times & \times & \times & \times & \times \\ 0 & 0 & 0 & \times & 0 & 0 \\ \times & \times & \times & \times & \times & \times \\ \times & \times & \times & \times & \times & \times \end{bmatrix}$$

where  $L_0$  is the  $n \times n$  short run impact matrix and  $L_\infty$  is the long run impact matrix. The

labels on the rows are the variables viz., loan loss provisions ( $\Delta \log(llp)$ ), dividends ( $\Delta \log(div_0)$ ), inflation ( $\pi$ ), GDP ( $\Delta \log(Y)$ ), interest rate spreads ( $(i^{plr} - i^{effr})$ ) and stock price ( $\Delta \log(sp)$ ). The columns represent the shocks such that the first column is provisions shock, second column is dividends shocks, third is demand shock, fourth is aggregate supply shock, fifth is monetary policy shock and sixth is news shock. The zero restrictions on each shock can be written in terms of an  $n \times 2n$  matrix  $Q_j$  such that

$$Q_j f(Z, B) e_j = 0 \quad (2.48)$$

Hence, there will be as many  $Q_j$  matrices as the number of shocks (Binning (2013)). The above mentioned restrictions translate into the following  $Q_j$  matrices. If  $q_j = \text{rank}(Q_j)$ , then columns in equation are ordered in descending order of rank of corresponding  $Q_j$  matrices.

$$Q_1 = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$Q_2 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$Q_3 =$$

$$Q_4 =$$

$$Q_5 =$$

$$Q_6 =$$

As suggested by Theorem 1 of RWZ, an SVAR is exactly identified if and only if  $\text{rank}(Q_j) =$

$n - j$  for  $1 \leq j \leq n$ . In this particular case, the rank for the restrictions on the provisions shock is  $q_1 = 5$  which is exactly equal to the rank suggested by Theorem 1 of RWZ. Hence the provisions shock is exactly identified. The rank on the dividends shock is  $q_2 = 1$  as opposed to the desired value of 4, rank on aggregate demand shock is  $q_3 = 1$  as opposed to desired value of 3, rank on aggregate supply shock  $q_4 = 0$  as opposed to desired value of 2, rank on monetary policy shock is  $q_5 = 1$ . Under specification 2 (AB-Specification-2), I assume that all variables respond to provisions shock in the short run and inflation rises on impact in response to a provisions shock. The provisions shock is no more exactly identified under this specification.

#### **2.8.4.6 Results**

Under Specification 1, provisions shock is exactly identified. Upon a provisions shock, dividends rise initially and starts declining after the third quarter and then declines permanently. Inflation rises after a zero impact response, and returns to zero only in the medium run. Interest rate spreads peak during the second quarter and decline only after the fourth quarter. GDP peaks in the third quarter and starts declining thereafter before returning to zero. Stock prices rise sharply on impact and start declining thereafter, reaching a trough during the third quarter before returning to zero (Figure A.16).

Under Specification 1, a monetary policy shock is set identified. Inflation and GDP decline while interest rate spreads rise on impact in line with the sign restrictions. However, the impact response of stock price to a monetary policy shock is ambiguous under sign restrictions, although the stock prices rise during the third quarter (Figure A.17). This response is different from the stock price response to monetary policy shock under SVAR, where stock prices increase sharply after a zero non-response and the rise is statistically significant from zero. This is also different from the response under sign restrictions under Mountford and Uhlig (2005) method, where stock prices rise significantly on impact.

Under Specification 2, inflation increases and GDP declines in line with the sign restrictions imposed. The impact response of stock prices to provisions is however ambiguous, although stock

prices decline in the third quarter (Figure A.18). Inflation and GDP declines in response to a monetary policy shock, while the response of stock prices is ambiguous (Figure A.19)<sup>1</sup>

## 2.9 Conclusion

This paper examines the impact of monetary and macro-prudential policy on asset bubbles within the framework of a canonical overlapping generations model with monopolistic competition, price setting in advance and financial frictions. Gali (2014) observed that a leaning against the wind monetary policy generates a larger volatility in the bubble than a policy of benign neglect. The results of this paper nests Gali's (2014) remarks that bubble volatility is minimised at  $\phi_q = -1 < 0$  which is indicative of passive monetary policy. However, it is observed that if the financial system is sensitive to changes in  $\phi^b$ , lower values of macroprudential parameter leads to gradual and marginal rise in interest rate spreads, contracting the bubble. But as the macroprudential parameter is tightened beyond a threshold value, bank accumulates provisions which induces them to assume more risks and hence credit varies positively with  $\phi^b$  above the threshold. The cost of intermediation impinges on the profitability of banks inducing compensating hike in lending rates. The abundant liquidity in the economy raises inflation and induces rise in policy rates and aggravates the volatility in the bubble. In sum, minimisation of bubble volatility necessitates a passive monetary policy response to the bubble but an active macroprudential policy, bounded above. It is also observed that stronger interest rate response of monetary policy to the bubble necessitates a stronger macroprudential response possibly to absorb the excess volatility generated by the monetary policy.

With respect to monetary policy, there is a conflict between stabilization of current aggregate demand (through the stabilization of volatility in dividends) and stabilization of future aggregate demand like Gali(2014). However, optimal macro-prudential policy might not have to strike a balance between stabilization of current aggregate demand which calls for an increasing cost of

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<sup>1</sup>I express my gratitude to Dr. Andrew Binning for having shared his code with me. The code used is from his working paper "Underidentified SVAR models: A framework for combining short and long-run restrictions with sign-restrictions" (2013) and can be found on his webpage.

intermediation and stabilization of future aggregate demand (bubbles) which requires a strong macro-prudential response to bubble volatility, at least upto a threshold.

The empirical results verify the 'provisioning cost' channel. A positive provisions shock induces an adverse aggregate demand effect due to restricted credit supply and a subdued anti-inflationary stance of monetary policy leading to gradual rise in interest rate spreads and the contraction of bubble component of stock prices. Similar results are obtained with respect to provisions shock with standard Taylor rule or augmented Taylor rule. Using US data, this paper finds that provisioning shock in general and dynamic loan loss provisioning shock, in particular reduces stock prices and dampens output growth as opposed to monetary policy. This result is substantiated both under recursive SVAR specifications as well as sign restrictions imposed according to Mountford and Uhlig (2005) specification. However, by combining sign and zero restrictions in an underidentified SVAR model proposed by Binning(2013),the paper finds that stock prices decline when variables are assumed to be responding to provisions shock only in the long run. However, when sign restrictions are imposed on inflation, impact response of stock price to provisions shock as well as monetary policy shock is ambiguous. However, stock prices decline during the second quarter in response to a provisions shock.

## **Chapter 3**

# **Financial Inclusion, Financial Stability and Credit Cycles in EMEs**

### **3.1 Introduction**

Financial Inclusion has been the cynosure of global attention for the past couple of years. There has been a welcome realisation among the international policy making units including the G-20 that financial inclusion is fundamental to improving the livelihoods of the poor as it enables them to run their businesses, build assets, smooth consumption and manage risks. From a policy perspective, there is an equal realisation that financial inclusion improves transmission of monetary impulses as a greater chunk of economic activity comes under the purview of interest rates (Mehrotra and Yetman; 2014). Moreover, access to formal savings and credit mechanisms inculcates savings behaviour and facilitates investments in productive pursuits like education and entrepreneurship, thus enhancing growth in human capital and narrowing income inequalities (Kunt and Klapper (2013)).

However, the benefits of financial inclusion notwithstanding, the impact of bank based financial inclusion on bank's stability which are the underpinnings of systemic stability has been a relatively lesser researched area, although there is persistent concern about it. This may partly be attributed to the scarcity and relative newness of data on financial inclusion and the nobility of the program. But post financial crisis, it is important to notice how financial innovations like these have been affecting the operating cost of banks and its overall soundness. The question that we are trying to ask is as banks adopt new methods to accommodate these un-banked set of new consumers, what im-



impact can we expect on banking stability and overall systemic stability. Access to low cost deposits may enhance the resilience of deposit funding base of banking sector in times of financial stress by reducing its dependence on non-core financing and pro-cyclicality risk, a point that has been well asserted by Hanning and Jansen (2010). In many countries like Peru, banking agents are also loan collectors that may facilitate better management of non-performing assets. But on the other hand, one thing that is common in these innovative practices is the intervention of a ‘third party’ either in the form of banking agent or mobile service provider that do not have a prior experience in handling financial services (BIS, 2015). Although reducing transaction cost for banks, contracting commercial third parties (banking agents) to offer basic financial services on behalf of the contracted bank endows the bank with operational risks. In many countries like Peru, Colombia, Mexico Brazil, Pakistan, Fiji and Philippines, banking correspondent agents (BCAs) are involved in customer due diligence measures (CDD) or primary customer identification required for account opening and other transactions. However, technological incompatibility with the realities of local agent locations as well as higher cost of technology operation in low traffic areas (low economies of scale) restrict the use of sophisticated fool proof technology like biometric identification. This raises questions about whether financial inclusion may compromise anti-money laundering and combating financing terrorism efforts (AML/CFT) of Financial Action Task Force (FATF) and whether these costs override the benefits of financial inclusion (CGAP, 2011). Further, depending on how policies are framed, the possibility of the system shaping up into an asymmetric financial inclusion process with higher financial risks where rapid credit growth may not be accompanied with commensurate growth in deposits cannot be discounted in low income economies. Which of these two forces may be operative in a financial system depends on a variety of factors including the quality of regulation.

This paper seeks to enhance our understanding of the role of financial innovations typical of economies engaged in bank based financial inclusion programs in the course of credit cycles. In pursuance of this objective, I introduce several financial frictions that capture the dynamics of

credit supply in such economies in a New Keynesian Stochastic General Equilibrium model. The paper is organised in the following order. Section 2 elaborates the definitions of financial inclusion and financial stability and brings out the conflict between the two goals. Section 3 sets out a literature review on the subject. Section 4 talks about the model, Section 5 is calibration and Section 6 elaborates the results. Section 7 produces the results of the alternative model. Section 8 Concludes.

### **3.2 What is Financial Inclusion?**

As the United Nations point out, 50 per cent of the world's total population do not have access to formal or semi-formal financial services like a bank account, life insurance, savings and payment options. This section of the population is said to be financially excluded. Based on World Bank's Global Findex data and focussing on low and middle income countries exclusively, the distribution of population concentrated in these countries that do not have even a single bank account is highly non-gaussian with the average percentage of population that is excluded financially as high as 66.7 per cent (Figure 3.1). To share some glaring facts, the World Bank data on financial inclusion (Findex 2011) shows that the percentage of population who do not have a bank account may range between 18 per cent in Mauritius to 99 per cent in Turkmenistan. If we remove one third of the lowest and one third of the highest observations from the sample, then this data ranges between a minimum of 63 per cent and a maximum of 79 per cent in the above mentioned set of countries. Cross section regression estimation based on Global Findex data shows that while females have less access to finance, access increases with age, education and income. So the youth, females, illiterate and the poor are more likely to be excluded from the formal financial system (Table 3.1).

Financial inclusion, then, to be precise, is the process of improving the effective access of working age adults to basic financial products supplied by formal and semi-formal institutions so

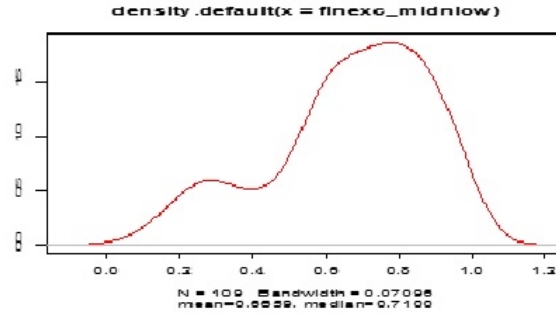


Figure 3.1: Kernel Density of percentage financially excluded in Middle and Low Income Countries

Table 3.1: **Results from Cross-Section Regressions**

<i>Variable</i>	<i>Coefficient</i>	<i>Std.Error</i>	<i>P-value</i>
Female	0.1777	0.0081	0.000
Age	-0.0074	0.0003	0.000
Education	-0.505	0.0069	0.000
Income	-0.192	0.0029	0.000
Constant	1.569	0.0898	0.000

as to reduce their dependence on informal financial architecture, which may be exorbitant and in some cases, exploitative. Effective access, in turn, involves convenient and responsible service delivery, at a cost affordable to the customer and sustainable for the provider (BBVA, 2015)

Financial inclusion as well as financial stability are both complex and multidimensional concepts that betray any universal definition. It is extremely difficult to present a comprehensive measure that appeals to all aspects of financial inclusion or financial stability. Nevertheless, some attempts have been made to develop such a measure. The GPFi endorsed a basic set of financial inclusion indicators at the G-20 Los Cabos Summit in 2012. This measures financial inclusion along three dimensions - (i)access such as points of service or number of e-money accounts (ii) usage such as number of depositors, borrowers, insurance policy holders per 1000 adults; and (iii) quality and delivery of financial services. Amidzic et al (2014) have developed a composite index of financial inclusion that addresses the issue of weighting as well as that of perfect substitutability

between dimensions. They have used factor analysis to identify financial inclusion dimensions and assign weights. The composite index is derived from a non-linear aggregation of intermediate dimensional indicators and is subsequently used to rank countries. However, it is currently available only for a handful of countries and is restricted to the period 2009 to 2013. Increasingly, policy makers are recognizing the importance of evidence-based decision making and the central role of data and measurement. Data on financial inclusion can enable identification of areas where policy is most needed, inform program design and policy choice, and facilitate monitoring and evaluation (IFC Discussion paper, 2011).

The definition of financial stability, on the other hand, range from a narrow focus to a more broader definition. ECB(2007) broadly defines financial stability as a condition in which the financial system comprising of financial intermediaries, markets and market infrastructure is capable of withstanding shocks and the unravelling of financial imbalances, thereby mitigating the likelihood of disruptions in the financial intermediation process which are severe enough to significantly impair the allocation of savings to profitable investment opportunities. The narrow definition tries to quantify financial stability by concentrating on the risks and vulnerabilities of the financial system and this is ably accomplished by defining financial instability (Gadanecz and Jayaram, 2009). According to Borio and Drehmann (2009), financial instability is referred to as a set of conditions that is sufficient to result in the emergence of financial distress/crises in response to normal-sized shocks which may originate either in the real or financial sector. Ferguson(2003) refers to financial instability as any situation where some important set of financial asset prices seem to have diverged sharply from fundamentals; and/or market functioning and credit availability, have been significantly distorted, domestically and/or globally; resulting in deviation of aggregate spending significantly from the economy's ability to produce. But as Borio and Drehmann (2009), point out that most definitions of financial stability have three common components - focus on the financial system as a whole, measure economic welfare and costs in terms of real economic activity and define it in terms of its opposite, financial instability which is more concrete and observable. In

this connection, many authors have also tried to develop a composite index of financial stability. A recent work in this context is the work of Karanovic and Karanovic (2015) who developed a financial stability index for the Balkan region by juxtaposing the IMF Financial Soundness and macro-prudential Indicators with World Bank development indicators and CESifo measures of World economic climate. They perform a Chanut-Laroque analysis of contribution to volatility levels in the aggregate stability index in order to explore which sub-indices explain the movements in the index value during the crisis period.

Financial inclusion can promote financial stability on many occasions. For example, correlated deposit withdrawals could be mitigated if bank deposits are diversified or greater share of adult population use bank deposits. Thus broader financial inclusion in bank deposits could significantly improve resilience of banking sector funding and thus overall financial stability (Cull et al; 2012, Han and Melecky; 2013). Banking agents, by ensuring deposit growth, can thus promote financial stability. Morgan and Pontines (2014) find some evidence that an increased share of lending to small and medium-sized enterprises (SMEs) aids financial stability, mainly by reducing non-performing loans (NPLs) and the probability of default by financial institutions. Also, financial inclusion and financial stability can be at loggerheads with each other at many ends. For example, in some cases the agents are entrusted with the job of customer verification at remote locations where the use of sophisticated instruments like biometric verification is difficult. Employing inexperienced agents without foolproof instruments can compromise the goals of anti-money laundering and combating of financing terrorism efforts at the global level. Financial inclusion may lead to rapid credit growth without expected growth in deposit base, triggering what we call in this paper a process of 'asymmetric inclusion' problem. Further, financial inclusion can be made possible only under a financially stable environment.

Given these significantly large numbers of financially excluded across the world, it is not surprising that in the last one decade, financial inclusion has acquired global attention. Overtime,

there has been a welcome realisation among the international policy making units including the G-20 that financial inclusion is fundamental for improving the livelihoods of the poor as it enables them to run their businesses, build assets, smooth consumption and manage risks. The G20 members have adopted Financial Inclusion Action Plan as a part of the financial sector reform agenda. The Global Partnership for Financial Inclusion (GPFI) was officially launched in December 2010 to institutionalize and serve as the inclusive platform for peer learning, knowledge sharing, policy advocacy and coordination among G-20 and non-G-20 countries on financial inclusion. The topic of financial inclusion is increasingly becoming important to global standard setting bodies for reasons ably summarized by Caruana (2012). As Caruana (2012) points out, policy makers are becoming acutely aware of the close nexus between financial inclusion, equitable growth and a stable financial system. Implicit in this awareness is the appreciation of the fact that financial exclusion is fraught with risks and costs to financial integrity given the fact that cash based world of financially excluded is less transparent adding to financial instability. Above all, there is an equivalent appreciation of the fact that innovation is a seminal aspect of financial systems supportive of equitable growth which in turn can bring unprecedented risks emerging from products, services and providers reaching services to the financial excluded population. The recently issued Basel III regulations thus also devoted a chapter to financial inclusion. In other words, there is no gainsaying financial inclusion is going to shape the structure of global policy making in the years to come.

In pursuance of the international recognition of the issue, there have been considerable efforts at the individual country level to work towards financial inclusion. The enthusiasm is substantiated by a recent survey results of the BCBS which finds that 63 per cent of the low income respondents had a national financial inclusion strategy and most of them have a financial inclusion mandate or goal at the organisational or national level (BIS, 2015). Countries, who have a weak financial institution base like Honduras, El Salvador and Nicaragua have preferred to work towards financial inclusion by allowing micro finance institutions into the policy space. Another set of countries

like Brazil, Mexico, India, Colombia, Kenya, Philippines, Peru and Turkey which had a reasonable bank outreach have taken to the route of bank led financial inclusion which includes opening bank branches in un-banked areas, branch less banking by allowing banking correspondents where banks have representatives who operates transactions outside the bank's branch network, allowing no frills deposit accounts, relaxing KYC (Know your customer) norms and financial literacy programs and above all digital banking practices.

In this paper, I particularly focus on bank based financial inclusion. I consider two different credit cycle models imbued with various characteristics typical of an economy adapting to financial inclusion *viz.*, disutility from bank deposits, loan default and banking correspondent agents intermediating between the bank and the household to reduce the costs of transiting. The first model characterises BCAs as intermediaries between the bank and the households and indulge only in cash in and cash out type of transactions. In the second model, BCAs are business facilitators and employed by the bank as loan advisors who are involved in the life cycle of the loan beginning with its paperwork, sanction, advising for productive end-use and their smooth repayment. To motivate the BCAs role as business facilitator, I model the BCAs as forward looking economic agents supplying their labor to the bank. The bank utilises BCA labor in a linear technology to influence the repayment rate along with two endogenous stochastic processes, technology shock and BCA productivity shock. I also assume that the BCAs exercise some market power and model them as monopolistic competitors. In other words, BCAs serve as bank products retailers that upgrade the product in terms of its specific features (access, price) and then sell them to households with a mark-up over the purchase price. I observe that a 100 basis point rise in mark-up rates of loan disbursing BCAs leads to an immediate 50 bp rise in the interest rate charged on consumption loans to impatient households in the second model. However, equilibrium loans to impatient households seem to be relatively inelastic with respect to the interest rate. They fall within the quarter but rise thereafter. The low default rates on loans which the bank ensures by employing the BCAs as facilitators in the loan life cycle sustains the demand for the loans despite rising interest rates. In

other words, BCAs working closely with the households in loan management imbibes confidence among both the households and banks about proper loan disbursal and recovery streamlining the credit cycle. In the first model, on the other hand, default rates are determined by exogenous processes and the BCAs provide price incentives to impatient households to recover the outstanding loan amount. In this model, a one standard deviation shock to mark up on loan disbursing BCA units propagates slowly to the interest rates charged on households as initially the adjustment cost of changing rates exceeds the benefits from higher interest rates as loan demand declines drastically. The impact of a positive shock to mark-up, however, is very concentrated in both the models. Aggregate consumption, deposits, asset prices and loans to firms continue to rise, while NPA ratio declines. However, in the first model, NPA ratio falls because of sharp decline in loans to impatient households, while in the second model, NPA ratio falls due to rise in repayment rates attributable to the greater involvement of the BCAs in the loan cycle. In sharp contrast, a positive shock to mark-up on loan recovery service charges leads to an across the board rise in interest rates which have a contractionary impact on all real variables. Default rates, however, rise since banks use the BCAs only as intermediaries to collect loan repayments but not as active participants in loan recovery.

### **3.3 Literature**

Economic literature in the past have tried to model 'financial exclusion' - although the literature abstained from phrasing the term - in the framework of Limited Asset market participation where a section of private agents are not forward looking optimising agents. So they do not participate in the asset market to smooth their consumption, instead, in the words of Mankiw(2000), they live from 'paycheck to paycheck'. Gali (2003) built on Mankiw's model and observed that allowing for 'rule of thumb' consumers in DSGE models produces closer fit of models results to data, a phenomenon which was not observed with the canonical models with government spending. Mehrotra and Yetman (2014) showed that optimal monetary policy implies a positive relationship



between the share of financially included households and the ratio of output volatility to inflation volatility. Among the two notable empirical studies in this area, Han and Melecky (2013) indicate that a 10 percent increase in the share of people that have access to bank deposits can mitigate the deposit growth drops (or deposit withdrawal rates) by about three to eight percentage points. The enhanced resilience of bank funding can then support overall financial stability of the banking sector and the entire financial system. They also found that this effect is likely to be much stronger in middle-income countries, which could face greater shocks to depositor confidence due to still developing trust in the banking sector and already high integration in global finance. Morgan and Pontines (2014) find some evidence that an increased share of lending to small and medium-sized enterprises (SMEs) aids financial stability, mainly by reducing non-performing loans (NPLs) and the probability of default by financial institutions. This suggests that policy measures to increase financial inclusion, at least to SMEs, would have the side-benefit of contributing to financial stability as well.

My work deviates from all the other work in two major aspects. First I focus on 'financial inclusion', rather than 'financial exclusion'. Second, the past literature treats the subject as a demand side problem, while I am trying to look at the issue from the supply side. I am trying to study the dynamics of an economy where providing finance to nook and corners of the economy may not be a cost effective option even for a well-regulated bank through conventional 'brick and mortar' banking. So while my study puts 'finance' at the centre stage of economic growth of both rural and urban economy as opposed to the view of Modigliani and Miller, it also highlights that financial innovations to reach out to the masses may bring additional dynamics into the economy. To the best of my knowledge this is the first paper which focusses on bank based financial inclusion and models the banking correspondent agents in a New Keynesian DSGE model. This paper relates to a wide body of literature that builds financial frictions into dynamic stochastic general equilibrium model. The widely used financial accelerator model of Bernanke, Gertler and Gilchrist (1999) (henceforth BGG) introduces frictions through agency costs by assuming a

variant of Townsend's 'costly state verification' where lenders pay a auditing price for observing the realized returns of borrowers. Costly verification introduces an inverse relationship between external finance premium and net worth of potential borrowers. The procyclicality of net worth and the ensuing countercyclicality of external finance premium leads to fluctuations in economic activity. Kiyotaki and Moore (1997) added muscle to BGG theory by looking at shocks to net worth emerging from changes in values of firm's assets and liabilities. They argue how persistent shocks can have a cumulative impact on asset prices, net worth of borrowers and through that on economic activity. Kiyotaki and Moore (1997) assumes away ex-post default as borrowers are required to pledge a collateral that eliminates the incentive to default. In contrast, Dubey (2005) and Lin (2014) model default in equilibrium and default is costly to lenders. They assume that borrowers are subject to non-pecuniary default penalties where the borrower loses reputation owing to default and pecuniary default penalties in the form of search costs of new loans after default. Iacoviello (2005) asserted that the strength of financial accelerator may not be uniform depending on the origin of shocks. While a demand shock may accelerate asset prices and consumer prices leading to higher overall spending, higher consumer prices may dampen adverse supply shocks if obligations are held in nominal terms. As opposed to the dynamics of market finance, a number of papers look at the financial frictions in institutional credit. Christiano, Motto and Rostagno (2010) (henceforth CMR) and Goodfriend and McCallum (2007) study the demand side of bank credit in a perfectly competitive banking market set up. On the other hand, Gerali et al (2010) examines the impact of supply side financial frictions on economic activity. They introduce a monopolistically competitive retail banking structure where interest rates are sticky and adjusted only infrequently. They find that shocks emerging from the banking sector explain the bulk of the contraction in economic activity. Sticky interest rate attenuate the effects of monetary policy shocks and financial intermediation increases the propagation of supply shocks.

This paper is closer in structure to Gerali et al (2010). But I use two types of default modelling strategies to highlight the economic situations of assetless borrowing households and asset owning

borrowing entrepreneurs. The rest of the description of the paper is produced under the model section. But prior to presenting the models, I present some empirical results based on difference in difference estimation.

### **3.4 Empirical Work**

I contribute to this growing literature by exploring the relationship between financial inclusion and stability in countries adopting banking correspondent model. I look at how financial inclusion through banking correspondence agents impacts the non-performing assets and z-score of the banks in such countries. A graphical comparison of non-performing assets to gross loan ratios in countries adopting banking correspondent model as opposed to others show that the latter share a similar trend but have a higher NPA ratio and the gap widened during the current financial crisis (Figure 3.2). The graphical inference although consistent with existing literature raises important pointers as to how adopting banking correspondent model bears an ameliorative impact on bad assets of a financial system. Is it the efficiency of the third party agents in introducing the right customer to the bank and continued efforts on their part in monitoring these customers that has lowered bad asset formation? Or is it that only countries which had a strong NPA management system took to financial inclusion through bank based programmes which in turn makes the financial inclusion variable an endogenous variable. My paper is an improvement on many previous papers that have tried to assess the impact of various factors on NPA generation in general, and the impact of financial inclusion on NPA creation, in particular. Unlike Beck et al (2012), I control for management of non-performing assets by various categorical variables that capture the asset classification differences across countries. I abstain from using any ratios in our model unlike Morgan and Pontines (2014) because ratios introduce an automatic bias in the models and may lead to misinterpretation of data. Further all these studies allow specification bias by assuming a linear relationship between financial inclusion and stability. I test for various spline fits in my study and also discover non linearity in many variables.

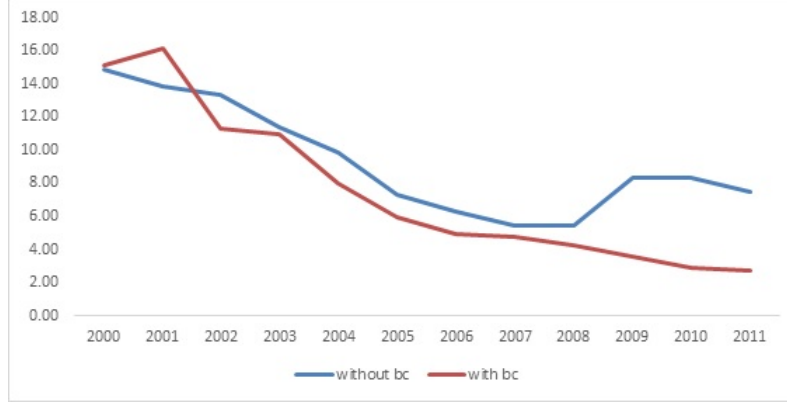


Figure 3.2: Average NPAs - Economies with Banking Correspondent vs Economies without Banking Correspondent

### 3.4.1 Identification Strategy

I approach to estimate the causal effect of financial inclusion on financial stability in three stages. One, at the country level where I use a difference in difference estimator to identify the causal effect of financial inclusion in ten countries where bank led financial inclusion has been introduced between 2001-2013.

$$Npa_{it} = \alpha + \delta_i + \gamma_t + \beta * FI + \theta * Z(it) + \varepsilon_{it}$$

Where  $i$  denotes countries,  $t$  denotes years,  $\delta_i$  captures country fixed effects,  $\gamma_t$  are year fixed effects,  $FI$  stands for dummy for financial inclusion which is the interaction term between the year the policy was introduced in the treatment country and a dummy that equals one for countries that had bank led financial inclusion (treatment) and that equals zero for all other countries in our sample,  $Z(it)$  are control variables that include log private credit to GDP ratio, a variable that proxies the quality of regulation in each country and average assets to equity ratio (leverage ratio) of microfinance institutions in countries. The latter is calculated by subtracting the Basel norm for capital adequacy from the existing capital adequacy for each country. At the second stage, I use the

Indian bank level data on non performing assets (Npa), advances (log\_adv), capital adequacy ratio (logcrar) and interest income (logint\_inc) to assess the impact of financial inclusion on stability. In 2005, the Reserve Bank of India issued circulars to all scheduled commercial banks to introduce financial inclusion plans. Only public and private sector banks were subject to this policy (treatment group) while foreign banks were excluded (control group). So we can expect to see a differential impact of this policy on public and private sector banks relative to the control group which are the foreign banks. Out of a total of 71 scheduled commercial banks in India, 46 are public and private sector banks. India has a consolidated banking system where number of banks are limited but each bank can open as many branches as it wants under the license of the central bank. As at end-March 2013, there were 105,437 commercial bank branches in India. I try to identify the impact of the policy on the non performing loans of these banks through differences in differences method for the period 2003-2013 like in equation (1). I chose India as detailed granular data is publicly available for India as opposed to other developing countries. The same exercise can be done for other countries subject to bank level data availability. I also include lerner index as a measure of competitiveness in the financial industry. It is envisaged that a more efficient and competitive financial system is expected to show up in better management of NPAs and low z-scores. Unlike Beck et al (2013), I abstain from using share prices and foreign currency denominated loans as a control variable because my sample concentrates on low and middle income countries many of which do not have a well-developed capital market or substantial foreign currency lending apart from the fact that lack of data reporting hinders the use of these variables for our sample of countries.

A crucial step that separates my study from earlier empirical work on financial inclusion is that I have created categorical variables to capture the country differences in asset classification, diversification and provisioning, the details of which is appended in the Appendix (Figure B.1 and B.2). Asset classification or the way the countries define non-performing assets and categorize them into sub-standard, doubtful and loss categories would have a significant impact on the movement of the NPA variable. The control group, in this case, are the other middle and low income countries. I use a panel of 143 countries for the period 2004-2011. I also work out difference in difference

estimates with respect to many other banking parameters like real loans, deposits, return on assets and return on equity. Further, I also run difference in difference regressions to assess the impact of the policy on various macro variables like the savings, consumption expenditure, food prices and unemployment.

Difference in Difference estimates using a panel fixed effects is a static analysis that allows us to capture the country-specific effects and the unobservable differences between countries. Using a panel data approach, one can control for the biases generated by potential heterogeneity and omitted variable problems (Beck et al, 2013). I improvise on this specification by fitting and testing for various non-linear models including general additive models and semiparametric specifications to arrive at the ideal model. But before doing this exercise for the panel dataset, as a preliminary test, I use the cross section data in Findex 2011 and test various linear and non-parametric nonlinear models to get a better idea of the functional form that defines the relationship between bank Z-score/NPAs and various financial inclusion measures. The assumption needed to guarantee that this identification strategy is valid is that, in the absence of FI, the average difference between outcome variables across countries (and banks in stage 2) with and without FI would have been the same post-introduction as pre-introduction. Following Bruhn and Love (2013), I test this assumption graphically whether the estimated change in outcome variables in countries (banks) with financial inclusion coincides with the time of introduction of the policy.

The country level annual data on NPAs, private credit to GDP and capital adequacy ratio have been obtained from world development indicators which provides a long time series of these aggregates. Annual data on Indian banks is sourced from the Reserve Bank of India and is publicly available data.

### **3.4.2 Results**

The results at the country level indicate that financial inclusion had a significant negative effect on non performing loans. The non performing loans declined by 41.9 per cent in countries that introduced bank led financial inclusion relative to the control group of countries during 2001-2013.

Other variables like capital adequacy ratio has the right sign but is not significant in explaining the variations in NPAs (Appendix Table 1). I work out both fixed and random effects model. The Hausmann test statistic is -7.34 and we fail to reject the null indicating that there is no significant difference between fixed and random effects model. In order to test the assumption graphically whether the estimated change in outcome variables (NPAs) in countries with financial inclusion coincides with the time of introduction of the policy, we compare the trends of average NPAs in treatment group and control group of countries for the period 2001-2013 (Figure 3.3). While the trends in NPA ratios in the two groups are same before introduction of policy, post introduction, while control group witnesses an increase in average NPA ratios, the treatment group sees a decline in average NPA ratios.

At the bank level in India, the FI interaction term is not significant in explaining the variations in NPAs between public and private sector banks (treatment group) vis a vis the foreign banks (control group) (Table 2), although other factors like quality of regulation (*logcrar*), credit disbursed (*logadv*) and interest income (*logintinc*) are significantly explaining the change in NPAs. However, we also worked out the regressions with cost of funds (*logcof*) as a dependant variable trying to see if catering to the low income population might have had any impact on the cost of funds for banks (Table 3). I find that financial inclusion of the unbanked increased the cost of funds by 18.1 per cent in the treatment group of countries relative to the control group and is significant. However, given the significant time effects, it's difficult to have a causal interpretation of the financial inclusion program on non performing loans of banks. Further, the time effects become more negative over time at least upto a point, suggesting that some other unobserved process was causing NPAs to decline.

On the other hand, when categorical variables pertaining to asset classification, diversification and competitiveness were introduced in the country difference in difference estimation, the impact of financial inclusion on stability becomes less stronger and the direction of the impact also reverses. It is found that financial inclusion accelerated financial instability as non-performing

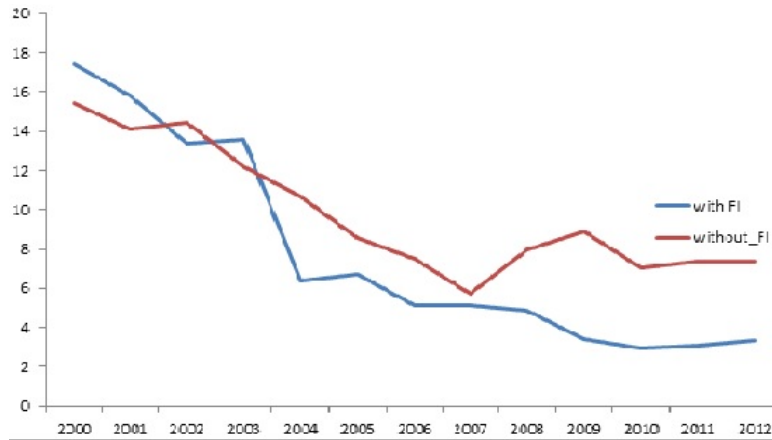


Figure 3.3: Average NPAs - Treatment Group vs Control Group

loans increased by 31.3 per cent in countries adopting bank based financial inclusion, although the result is not statistically significant from zero (Appendix Table 2). In fact, it is observed that higher growth of credit (business) and increasing competitiveness of the financial system bears a statistically significant ameliorative impact on non-performing loans. Moreover stricter the norms of sub-standard loan classification that the bank observes, higher are the non-performing loans.

To avoid any biased estimates due to misspecification of the functional form, I fitted various non-parametric models using the World Bank Financial Inclusion data for 2011 which provides the basic core set of financial inclusion measures for countries. I used these financial inclusion measures with the existing dataset but restricted the sample to the year 2011 as the financial inclusion measures are available only for that year. As a visual check for functional forms, I plotted the spline fits for all continuous variables used in the model, some of which are produced in Figure 3.4. I cross checked the non-linear models against linear, quadratic and logarithmic fits by conducting Chi square tests to arrive at the optimal model (Table 3.2). As the plots indicate, I find considerable evidence of real GDP per capita varying non-linearly with respect to most of the dependant variables including Bank Zscore, NPAs and savings. The bank Z score increases categorically with the rise in per capita GDP until GDP hits moderately high levels (Figure 3.4). The estimates for lending rate and percentage adults with accounts are essentially linear.



Table 3.2: Chi-square Test Results

	Linear	Quadratic	Logarithms
Real GDP growth (rgdp_g)	0.01662	0.01662	-
Real Credit Growth (realloans)	0.1043	0.0328	0.03244
Real Lending-rate (rlendingrate)	0.9891	0.9891	-
Real Exchange rate (rer)	0.007308	0.007308	0.02642
%adults with account	0.9889	0.9889	-

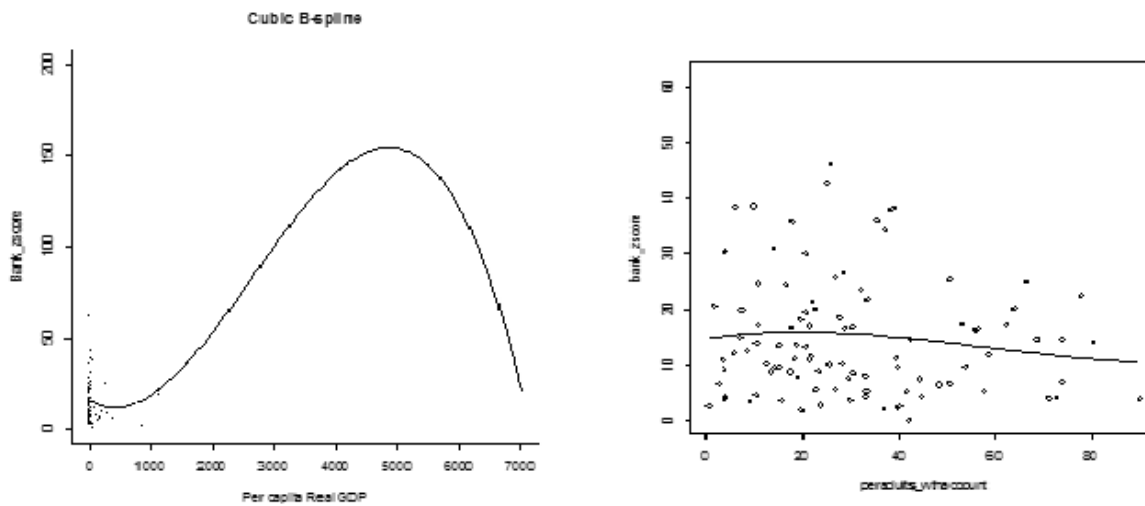


Figure 3.4: Financial Inclusion and Bank z-score

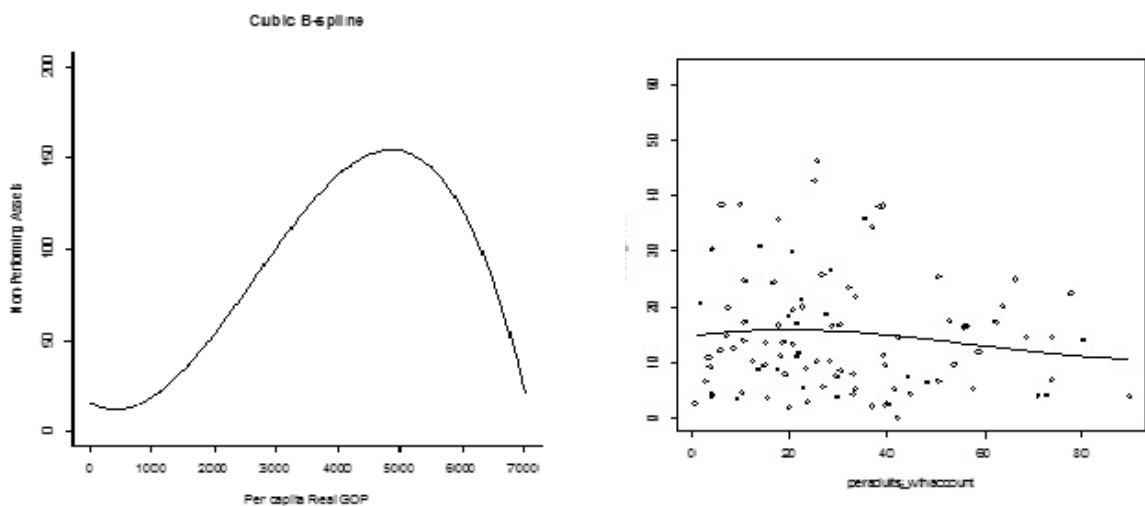


Figure 3.5: Financial Inclusion and NPAs

### 3.5 An Overlapping Generations Model

We extend the simplest overlapping generations model proposed by Samuelson(1958) and built on by Diamond(1965) to understand the long run competitive equilibrium in an economy with heterogenous agents including agents that opt out of the financial system and then explore the effects on this equilibrium of introduction of basel regulated banks. Each period  $t$ , a population  $N_t$  is born of which  $\alpha$  are type I consumers and  $(1 - \alpha)$  are type II consumers and each live for two periods. So in any period  $t$ , we have  $N_t$  young households coexisting with  $N_{t-1}$  old households. The economy produces a single consumption good that can be consumed either in that period or stored for one period. The good can also be used by firms for production of the single good  $y$ . An individual born at time  $t$  consumes  $c_{it}$  in period  $t$  and  $c_{i,t+1}$  in period  $t+1$ ,  $i \in [1, 2]$ , where subscripts refer to the types of consumers. We first consider the decentralised competitive equilibrium.

#### 3.5.1 Type I Agents

Type I agents are assumed to maximize their lifetime discounted utility function given as

$$u(c_{i,t}) + \beta u(c_{i,t+1})$$

s.t.

$$c_{1,t} + s_1 = \omega$$

$$c_{1,t+1} = s_1$$

where  $\beta$  is the subjective rate of time preference. We assume rate of time preference is same across types but later relax this assumption. The individual works in the first period supplying inelastically one unit of labor and earning a real wage of  $\omega$  that is paid in terms of consumption

good.

### 3.5.2 Type II Agents

Type II agents are assumed to maximize their lifetime discounted utility function given as

$$u(c_{2,t}) + \beta u(c_{2,t+1})$$

s.t

$$c_{2,t} + s_2 = \omega$$

$$c_{2,t+1} = (1 + r_{t+1})s_2$$

They lend their savings to the firms for which they are paid a rent of  $r_t$ . The savings of type II household enable the generation of capital stock that is used to produce output in combination with labor supplied by young generation in period t+1. The population grows at the rate n such that  $N_t = (1 + n)^t N_0$  (Blanchard and Fischer). Thus the younger generation of type II consumers constitute the supply side of capital market (Diamond, 1965).

### 3.5.3 Firms

The firms produce a single good y using a neoclassical production function technology that observes Inada conditions. Thus

$$y = F(K, N), F'(K) > 0, F''(K) < 0.$$

### 3.5.4 Optimisation

For simplicity of exposition, we assume that the functional form of  $u(\cdot)$  is logarithmic and  $y = k_t^\gamma$ . So from first order conditions of the two types of consumers and firms, we have

1. Type I Consumers:  $c_{1,t} = f(w_t), c_{1,t+1} = f(w_t)$
2. Type II Consumers:  $c_{2,t} = f(w_t, r_{t+1}), c_{2,t+1} = f(w_t, r_{t+1})$
3. Firms:  $w_t = F(k_t) - k_t F'(k_{t+1}), r_{t+1} = F'(k_{t+1})$
4. Goods Market Equilibrium:

(i) Output is distributed between consumption of type I agents, consumption in type II agents and investment.

$$y_t = \alpha(c_{1,t} + \frac{c_{1,t-1}}{(1+n)}) + (1-\alpha)(c_{2,t} + \frac{c_{2,t-1}}{(1+n)}) + k_t - \frac{k_{t-1}}{(1+n)}$$

(ii) Also the savings that are channelled into capital formation is provided by only  $(1-\alpha)N_t$  of the population at any time t. Thus

$$K_{t+1} - K_t = (1-\alpha)N_t s_2(w_t, r_{t+1}) - K_t$$

$$\text{or, } k_{t+1} = \frac{(1-\alpha)}{(1+n)} s_2(w_t, r_{t+1})$$

Equation 1 indicates that larger the number of people that are outside the system, smaller is the size of capital formed in any period. So exclusion hurts economic growth.

### 3.5.5 Dynamics and Stability

Differentiating equation (1) w.r.t  $k_t$  and suppressing subscript 2, we have

$$\frac{dk_{t+1}}{dk_t} = \frac{(1-\alpha)}{(1+n)} \frac{(-1)s_w k_t \frac{d^2 f(k_t)}{dk_t^2}}{(1 - \frac{(1-\alpha)}{(1+n)} s_r \frac{d^2 f(k_{t+1})}{dk_t^2})}$$

while  $0 < s_w < 1$ , the signs of  $s_r$  is ambiguous. If  $s_r > 0$  and given that  $\frac{d^2 f(k_t)}{dk_t^2} < 0$ , equation 2 is positive. However, comparing it to the original expression in Samuelson (1965), this is magnitudinally smaller if  $\alpha$  is high. So the saving loci in an economy with heterogeneous agents is below the saving loci of an economy with identical agents which implies that steady state capital in an economy with limited market participation is lower than that in original Samuelson economy.

I extend the canonical model to a heterogeneous agent model consisting of three agents - financially included savers and borrowing households and financially excluded households. Suppose every period,  $N_t$  agents are born in the economy of which a proportion  $\alpha_1$  agents are financially ex-

cluded, while  $\alpha_2$  agents are savers who deposit an amount  $d_t$  into the bank and the rest  $1 - \alpha_1 - \alpha_2$  are borrowers that borrow an amount of  $b_t$  in the economy. Each of these households live for two periods and the proportion in the population remains constant in each period. I assume that the financially excluded household consume an amount  $c_{11}$  when young (period 1) and  $c_{12}$  during old age. They also save an amount  $s_1$  in period 1. So financially excluded households maximise

$$\max \log(c_{11,t}) + \beta^r \log(c_{12,t+1})$$

subject to

$$c_{11,t} + s_{1,t} = w_t$$

$$c_{12,t+1} = s_{1,t}$$

Similarly the young savers in the economy distribute their wage income into consumption  $c_{21,t}$  and deposit  $d_t$  into a bank and consume out of their interest income proceeds during old age. They maximise

$$\log(c_{21,t}) + \beta_p \log(c_{22,t+1})$$

subject to

$$c_{21,t} + d_t = w_t$$

$$c_{22,t+1} = (1 + r_{t+1}^d) d_t$$

The first order conditions lead to the following linear relationship between consumption in old and young age

$$c_{22,t+1} = \beta^p (1 + r^{d,t+1}) c_{21,t}$$

Borrowers maximise the following lifetime utility function

$$\max. \log(c_{31,t}) + \beta^i \log(c_{32,t+1})$$

subject to

$$c_{31,t} = w_t + b_t$$

$$c_{32,t+1} + (1 + r_{t+1}^b) b_t = 0$$

I assume there exists a bank which issues deposit liabilities to savers and makes loans to households ( $b_t$ ) and firms ( $k_t$ ). The bank is subject to regulatory restrictions. One, the bank needs to maintain a capital to risk weighted assets ratio of at least  $v^b$ .  $\omega_1$  and  $\omega_2$  are the weights assigned by the bank to production and consumption loan, respectively. In addition, in line with the requirement under Basel III, I assume that the bank needs to maintain a minimum net financial stability ratio of 1. According to this regulation, the bank must assign a weight of 95 per cent to household deposits which are stable and a weightage of 100 per cent to bank capital. Loans to retail and small business are allotted a weightage of 65 per cent. The banks objective function is given by

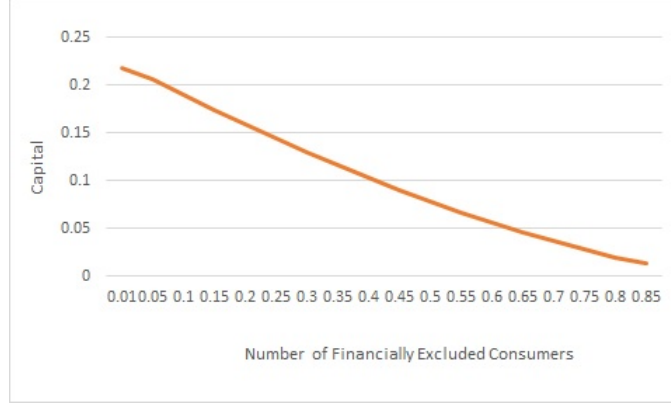


Figure 3.6: Capital Formation under Financial Exclusion

$$\begin{aligned}
P_t = & (1 + r_t^k)k_{t-1} + (1 - \alpha_1 - \alpha_2)(1 + r_t^b)b_{t-1} - \alpha_2(1 + r_t^d)d_{t-1} - K_t^b \pi_t \\
& - 0.5k_{kb}(K_t^b/(\omega_1 K_t + \omega_2 b_t) - v^b)^2 K_t^b - 0.5k_{kv}(\frac{K_t^b + v_{1,t}d_t}{v_2(K_t + d_t)} - v^v)K_t^b
\end{aligned} \tag{3.1}$$

Simulation of the model shows that capital formation in the economy steadily declines with the number of financially excluded (Figure 3.6).

### 3.6 New Keynesian DSGE Model

We follow the basic structure of Gerali et al (2010), yet we deviate from their model in several aspects so as to include various financial inclusion features of the economy. The first significant feature of the paper is to model the institution of banking correspondent agents as a major conduit for enabling financial inclusion in bank based systems. I define banking correspondent agents (BCAs) as producers of three types of services namely, the rural loan distribution services, rural deposit collection services and interest and principal collection services. For the convenience of modelling, BCAs can basically be seen as retailers of bank products who are operating with a semblance of market power. In recent years, this assumption has been more close to reality. There has been an increasing realization that regulatory prohibition on agents charging the customer directly

for their services or quantitative embargoes on how much banks can charge customers for agents services can endanger the viability and continuity of branchless banking. In recognition of this, in some countries like India, Reserve Bank of India has permitted banks to charge reasonable fees to customers for using agents services after approval of bank's board (November 2009). On the other hand, Latin American countries allow banks to charge for agent transactions, but banks abstain from this measure due to affordability or competitiveness concerns. But in some cases like Tanzania and Philippines, the agents have been allowed to set their own fees (CGAP, 2011). So in this sense, monopolistic competition amongst BCAs is a fair assumption for the model. The BCA retailers upgrade the product in terms of packaging and branding and finally sell them to households by applying a mark up over the price at which they bought from the bank. In the benchmark model, BCAs play the role of intermediaries or a delivery channel between the bank and the household and involved only in cash in and cash out type of transactions. In an alternate specification, the BCAs loan payment collectors are also modelled as forward looking economic agents whose labor services are hired by the banks to influence the repayment rates (default rates). In other words, banks can assert partial control over the default rates by engaging BCAs who involve themselves directly with the potential borrowers and collect information towards assessing their loan eligibility with reference to the local economic environment, household's historical default position and current economic status. In some cases, BCAs keep vigil over the end-use of the loan and provide necessary advisory services to the household to ensure past loan repayment and fresh loan processing. This model highlights BCAs as business facilitators in addition to the core traditional role (Wright et al, 2013)

Secondly, we deviate from most existing models in modelling default. Most of the existing literature follows Kiyotaki and Moore (1997) who assumes away ex-post default as borrowers are required to pledge a collateral that eliminates the incentive to default. Following Dubey et. al (2005) and Lin (2014), I wanted default to exist in equilibrium and costly to lenders as well as borrowers. However, allowing for endogenous default rates is intuitively incompatible with the essence of the model as I am talking about impatient rural households that neither have collateral



to pledge or nor they choose the default rates. Inability to repay loan is often not by choice but an outcome of technological or weather shocks. So I allow for non-pecuniary default penalties as in Lin (2014) for the impatient household as they incur reputation risks for not returning the loans. However, to motivate financial inclusion, I stop short of introducing pecuniary default penalties.

### **3.6.1 Households**

There is a continuum of households of measure one. To ensure that lending and borrowing takes place in equilibrium, we allow for the existence of three non-identical economic agents - Patient households and impatient households - and a rural entrepreneur. Patient households consume, work and acquire financial assets, while impatient households consume, work and borrow from banks. The entrepreneurs produce a homogenous intermediate good by hiring labor from both the households. The economic agents are differentiated by their degree of impatience which is reflected in the discount factors.

Banks issue deposit liabilities that are subscribed by patient households. The Bank provides un-collateralised consumption loans to impatient households and collateralised loans to entrepreneurs. The entrepreneurs borrow from the banks against their accumulated housing stock. However, Banks cannot directly reach the household customers and have to depend on intermediaries to reach out their services to them. Hence, they coordinate with banking correspondent agents (BCAs) to facilitate financial services to the households. There are three types of BCAs that coordinate between banks and households - deposit collectors, loan disbursers and loan collectors. These banking correspondent agents operate in a monopolistically competitive environment producing differentiated services. We allow for several sources of nominal rigidities - goods market retailers, BCA loan collection retailers, deposit collection retailers where all of them face quadratic price adjustment costs.

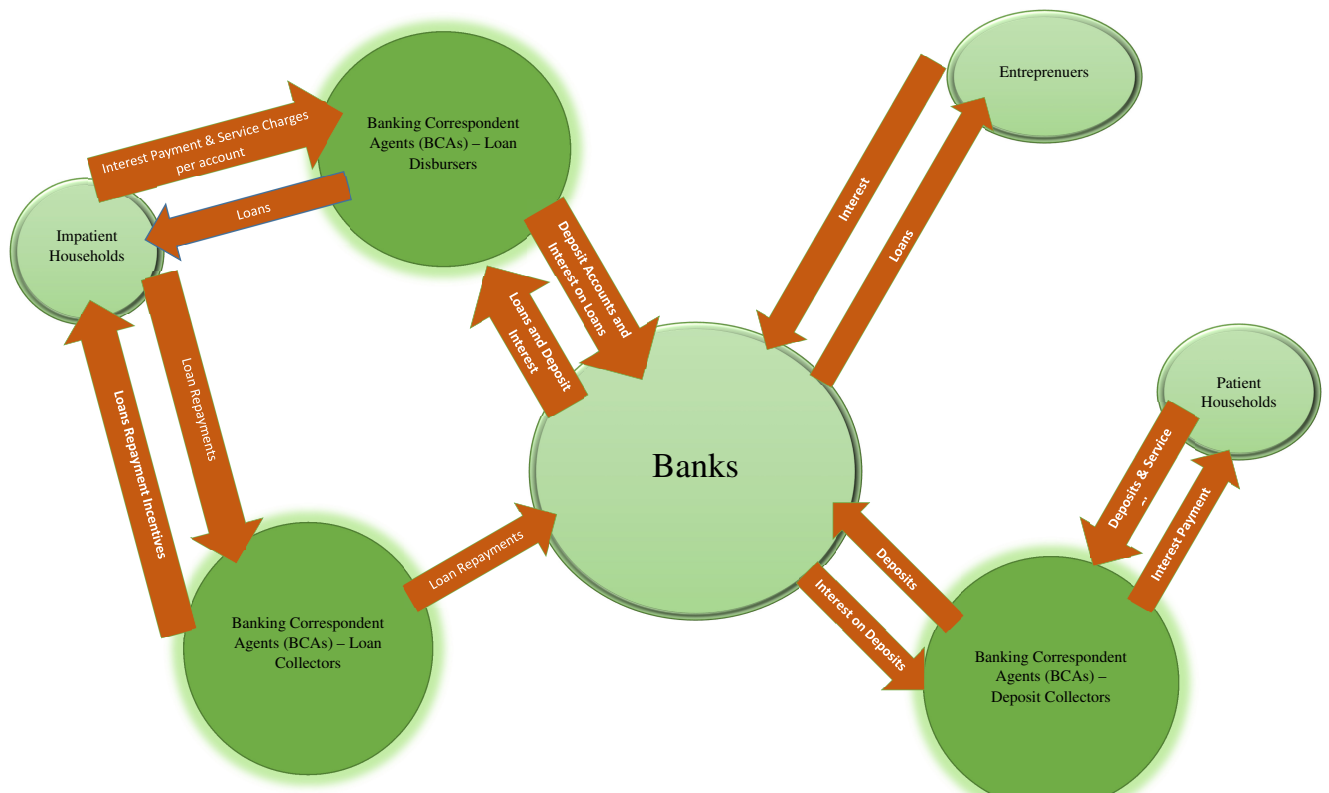


Figure 3.7: Schematic Diagram of the Model

### 3.6.1.1 Patient Households

The representative rural household maximises expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_p^t [(1 - a_p) \varepsilon_t^{z,p} \log(c_t^p(i) - a_p c_{t-1}^p) - \varepsilon_t^{l,p} \ln(n_t^p) + (1 - \varepsilon_t^d) D_t]$$

which depends on current individual and lagged aggregate consumption  $c_t^p$ , deposits and hours worked. He supplies labor to the intermediate goods sector,  $n_t^h$  for which they are paid wages  $w_t^p$ . In addition, the household incurs a dis-utility while banking in terms of paperwork required or labor time sacrificed to access the bank to avail its services. Such customers do not prefer to use the bank for regular savings but rather to receive government payments or for withdrawals. The stochastic shock,  $\varepsilon_t^d$  captures the opportunity cost of banking to the household in terms of wages lost, lost child care or other important household work. We allow for a preference shock ( $\varepsilon_t^{z,p}$ ) and a labor supply shock ( $\varepsilon_t^{l,p}$ ) in patient households. The household chooses consumption and amount of deposits which is the only available savings instrument and allocates labor to the intermediate goods sector subject to the following budget constraint.

$$c_t^p + \frac{D_t}{\gamma^d} + \gamma^d x_{1,t}^d \leq w_t^p n_t^p + \frac{(1 + r_{t-1}^d) D_{t-1}}{\gamma_{t-1}^d \pi_t} + t_t^p$$

The household allocates his income from the labor market, gross interest income from deposit last period and lump-sum transfers which includes dividends from banking correspondent sector into consumption expenditure, real balances and deposits next period. Additionally, the household pays a price of  $x_1^d$  per deposit account that it opens with the bank to the banking correspondent agent that intermediates between the bank and the household. The first order conditions with respect to this optimisation can be written as under

$$\frac{\varepsilon_t^{z,p}(1-a^p)}{c_t^p(i)-a^p c_{t-1}^p} - \lambda_t^p = 0$$

$$\varepsilon_t^{l,p} = \lambda_t^p w_t^p n_t^p$$

$$(1 - \varepsilon_t^d) + \beta^p \lambda_{t+1}^p \frac{(1+r_t^d)}{\pi_{t+1}} = \lambda_t^p$$

### 3.6.1.2 Impatient Household

The representative urban impatient household  $i$  maximizes the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_t^i [(1-a_i) \varepsilon_t^{z,i} \log(c_t^i(i) - a_i c_{t-1}^i) - \varepsilon_t^{l,i} \ln(n_t^i) - \theta^i (1 - f_{t-1}^b) \frac{b_{t-1}}{\pi_t}]$$

which allows for superficial habit consumption as in patient households and depends on current individual and lagged aggregate consumption  $c_t^i$ , labor supplied to the intermediate good producers,  $n_t^i$  for which they are paid wages  $w_t^i$ . In addition, the household incurs a disutility from the reputation lost due to any default on loans where  $(1 - f_t^b)$ , is the rate of default.

$$c_t^i + \frac{(1+r_{t-1}^b)f_{t-1}^b b_{t-1}}{\gamma_{t-1}^b \pi_t} + \gamma_{1,t}^b x_{1,t}^b \leq w_t^i n_t^i + \frac{b_t}{\gamma_{1,t}^b} + \tilde{r}_{t-1} f_{t-1} b_{t-1}$$

The household distributes its labor income and proceeds from unsecured consumption loans and transfer payments to repayment of past loans and consumption today. The household has to pay to the banking correspondent agent to obtain the loans from the bank which include opening an account with the bank and completing necessary paperwork. Further banks have to make efforts to recover its loans from the household. Banking correspondent agents are employed to advise and consult with the household and facilitate their repayment of loans. These agents incentivise the household to pay off the loans by offering a certain percentage ( $\tilde{r}_t$ ) of the loan amount as a relief.

The first order conditions with respect to this optimisation can be written as below

$$\begin{aligned}\frac{\varepsilon_t^{z,i}(1-a^i)}{c_t^i(i)-a^i c_{t-1}^i} - \lambda_t^i &= 0 \\ \varepsilon_t^{l,i} &= \lambda_t^i w_t^i n_t^i \\ \beta^i \theta^i (1-f_{t+1}^b) &= \lambda_t^i \pi_{t+1} + \beta^i \lambda_{t+1}^i (\tilde{r}_t f_t^b - (1+r_t^b) f_{t+1}^b)\end{aligned}$$

### 3.6.2 Entrepreneurs

The representative rural entrepreneur  $i$  maximizes the expected utility

$$E_0 \sum_{t=0}^{\infty} \beta_r^t [(1-a_r) \varepsilon_t^{z,r} \log(c_t^r(i) - a_r c_{t-1}^r) + \varepsilon_t^h \log(h_t)]$$

which depends on current individual and lagged aggregate consumption  $c_t^e$  and utility from housing. The household chooses consumption and amount of housing stock subject to the following budget constraint.

$$c_t^r + w_t^p n_t^p + w_t^i n_t^i + (1+r_{t-1}^r) \frac{b_{t-1}^r}{\pi_t} + q_t^h (h_t - h_{t-1}) + q_t^k (k_t - (1-\delta)k_{t-1}) \leq b_t^r + \frac{y_t}{x_t} + \psi(u_t(i))k_{t-1}$$

The entrepreneur allocates the proceeds from his output and loans from the bank into consumption expenditure, repayment of past loans, working capital expenditure and investment into fresh capital.

In addition to the budget constraint, the rural entrepreneurs are also subject to an endogenous collateral constraint: the expected value of their housing stock must guarantee repayment of debt and interests.

$$(1 + r_t^r) b_t^r \leq \bar{s}_i E_t(q(t+1)^h h_t^r p i_{t+1})$$

where  $\bar{s}_i$  is the loan to value ratio selected by the central bank. The first order conditions are given as

$$\frac{\varepsilon_t^{z,r}(1 - a^r)}{c_t^r(i) - a^r c_{t-1}^r} - \lambda_t^r = 0$$

$$\lambda_t^r((1 - \alpha)\mu^l y_t^e / n_t^p - w_t^p) = 0$$

$$\lambda_t^r((1 - \alpha)\mu^l y_t^e / n_t^i - w_t^i) = 0$$

$$\frac{\varepsilon_t^h}{h_t} - \lambda_t^r q_t^h + \beta^r \lambda_{t+1}^r q_{t+1}^h + \mu^r s_t^i q_{t+1}^h \pi_{t+1} = 0$$

$$\lambda_t^r - \beta^r \frac{(1 + r_t^r) \lambda_t^r}{\pi_{t+1}} - \mu_t^r (1 + r_t^r)$$

$$\lambda_t^r q_t^k = \beta^r \lambda_{t+1}^r (q_{t+1}^k (1 - \delta) + \frac{\alpha y_{t+1}^e}{x_{t+1} k_t(i)} - \psi(u_{t+1}(i)))$$

$$\lambda_t^r (r_t^k - \zeta_1 - \zeta_2(u_t - 1))$$

### 3.6.3 Goods Retailers

The retail goods market is monopolistically competitive. Retail prices are sticky and indexed to a combination of past and steady state inflation, with relative weights given by  $i_p$ . If retailers want to change their price beyond what indexation allows, they incur a quadratic adjustment cost parametrized by  $k_p$ . Retailers choose  $P_{t,j}$  so as to maximize

$$E_0 \Lambda^r [P_t(j) y_t(j) - P_t^w y_t(j) - \frac{\kappa_y}{2} (\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{i_p} \pi (1 - i_p))] ]$$

demand schedule derived from consumer's maximization where  $\varepsilon_t^y$  is stochastic demand price elasticity used in Gerali et al(2010).

### 3.6.4 Banks

Banks produce deposit liabilities and distributes loans to impatient households indirectly through the loan disbursing BCAs and directly (without BCAs) to entrepreneurs. The Bank has to manage the capital position. As in Gerali et al, bank capital is fixed in the short run and adjusted slowly through accumulation of retained earnings. The BCAs are retailers of bank's savings and loan products. The deposit collecting BCA collects deposits  $d_t^p$  from patient households (and BCA loan advisors in model 2) and passes the raised funds to the bank at a rate  $r_t^{i,b}$ . The BCA loan disbursers obtain funds from the bank at the rate of  $R_t^b$  and then differentiates them and sells them to impatient households by applying a mark-up. The bank combines the deposits with bank capital to issue loans. The bank, is however, subject to a quadratic cost, quantified by a coefficient  $k_{kb}$  and proportional to outstanding capital, whenever capital to assets ratio deviates from a norm  $v^b$ , stipulated by the Basel Committee on Banking Supervision.

$$\pi K_t^b = \delta_b K_{t-1}^b + j_{t-1}^b$$

where  $j_t^b$  are real profits made by banks and  $\delta_b$  are resources used up in managing bank's capital as defined in Gerali et al. The bank's profit function may be written as

$$P_t = x_{2,t}^d + x_{2,t}^b + (1 + r_t^b)b_t f_t^b - b_{t+1}\pi_t + (1 + r_t^r)b_t^r - b_{t+1}^r + D_{t+1}\pi_t - (1 + r_t^d)D_t - (\tilde{R}_t)(f_t^b)b_{t-1}^b - K_t^b - \frac{\hat{u}k}{2}\left(\frac{K_t}{B_t} - v^b\right)^2 K_t \quad (3.2)$$

Portfolio investment is however constrained by availability of funds.

$$B_t = D_t + K_t$$

where B is the total loans,  $B_t = b_t + b_t^r$ . I use this equation to eliminate from the profit equation to get the revised profit equation

$$P_t = x_{2,t}^d + x_{2,t}^b + (1 + r_t^b)b_t f_t^b + (1 + r_t^r)b_t^r - (1 + r_t^d)b_t - (1 + r_t^d)b_t^r + (1 + r_t^d)K_t - (\tilde{R}_t)(f_t^b)b_{t-1}^b - K_t^b - \frac{\hat{u}k}{2}\left(\frac{K_t}{B_t} - v^b\right)^2 K_t \quad (3.3)$$

The bank chooses the amount of loans to maximize the profits which is an unconstrained maximization of the above profit equation. The first order conditions yields the following two equations

$$(1 + r_t^b)E_t f_t^b = (1 + r_t^d) + (\tilde{R}_t)^b E_t f_t^b - k_{kb}(K/B - v)(K/B)^2$$

$$(1 + r_t^r) = (1 + r_t^d) - k_{kb}(K/B - v)(K/B)^2$$



In an alternative model, the price channel between banks, BCAs and households is replaced with an interest rate channel and an additional economic agent, the loan advising BCAs who are forward looking agents who spend their wage and savings proceeds on consumption expenditure and deposits in period  $t$ , is added. So the bank receives deposits from two sources, the impatient households and BCAs. Further, as explained above, it is also assumed that with the help of BCAs, the bank can influence repayment rates. So the bank maximises profits subject to the following linear constraint.

$$f_t^b = z_t^e z_t^b n_t^b$$

where  $z_t^e$  and  $z_t^b$  are two stochastic processes pertaining to total factor productivity and productivity of BCAs.  $n_t^b$  is the labor supplied by BCAs to banks. The first order conditions are modified accordingly.

### **3.6.5 Banking Correspondent Agents**

Modelling Banking correspondent agents (henceforth BCAs) is the most important contribution of this paper. BCAs can be looked as market institutions that lower the cost of reaching banking services to the masses. I envisage a BCA as producing three potential intermediate service inputs for the bank - rural loan collection services (L), loan disbursal services and rural deposit collection services (D).

#### **3.6.5.1 Loan Disbursal Retailers**

The retail BCA loan disbursal market is monopolistically competitive. The BCA loan disbursers obtain loan accounts from the bank and then differentiates them and resells them to impatient

households by applying a mark-up,  $x_3^d$ . If retailers want to change their price beyond what indexation allows, they incur a quadratic adjustment cost parametrized by  $k_l$ . Retailers choose  $P_t^d$  so as to maximize

$$\max E_0 \sum \Lambda_{0,t}^r [P_t^b(j) \gamma_t^b(j) - p_t^b \gamma_t^b(b) - 0.5 * k_l (\frac{P_t^b(j)}{p_t^b(j)} \gamma_t^b)]$$

s.t

demand schedule for BCA loan services by banks

$$\gamma_t^b(j) = (\frac{p_t^b(j)}{p_t^b})^{\epsilon_f} b_t$$

### 3.6.5.2 Deposit Collectors

The retail BCA deposit collection market is also monopolistically competitive. The BCA deposit collectors collect deposits from the household at the rate of  $r_t^d$  and resells them to banks at a rate of  $r_t^{i,b}$ . If retailers want to change their price beyond what indexation allows, they incur a quadratic adjustment cost parametrized by  $k_d$ . Retailers choose  $r_t^d$  so as to maximize

$$\max E_0 \sum \Lambda_{0,t}^r [P_t^d(j) \gamma_t^d(j) - p_t^d \gamma_t^d(j) - 0.5 k_d (\frac{p_t^d}{p_{t-1}^d} - 1)^2 p_t^d \gamma_t^d]$$

s.t demand schedule for BCA deposit services by banks given by

$$\gamma_t^d(j) = (\frac{p_t^d(j)}{p_t^d})^{\epsilon_D} d_t$$

### 3.6.5.3 Principle and Interest Payment Collectors

The retail BCA loan collection market is monopolistically competitive. The BCA loan collectors collect loans from the household by offering them incentives at the rate of  $(\tilde{r}_t)^b$  and then differentiates them and resells them to banks by applying a mark-up. If retailers want to change their price beyond what indexation allows, they incur a quadratic adjustment cost parametrized by  $k_f$ . Retailers choose  $(\tilde{r}_t)^b$  so as to maximize

$$\max E_0 \sum \Lambda_{0,t}^r [\tilde{R}_{t-1}(j) \gamma_{t-1}^b(j) - (\tilde{r}_{t-1}) \gamma_{t-1}^b j - 0.5 k_f (\frac{(\tilde{r}_t)}{(\tilde{r}_{t-1})} - 1)^2 r_t \gamma_{t-1}^b]$$

s.t demand schedule of banks for BCA loan collection services given by

$$\gamma_{t-1}^b(j) = (\frac{\tilde{r}_t(j)}{\tilde{R}_t})^{\varepsilon_f} b_{t-1}$$

### 3.6.6 Monetary policy

The central bank sets the policy rate at

$$(1 + r_t) = (1 + r)^{(1-\phi_r)} (1 + r_{t-1})^{(\phi_r)} (\frac{\pi_t}{\pi})^{(\phi_\pi(1-\phi_r))} (\frac{y_t}{y_{t-1}})^{(\phi_y(1-\phi_r))}$$

where  $r$  is the steady state policy rate.

### 3.6.7 Market Clearing Equations

Goods Market Equilibrium:  $y_t = c_t + q_t^k(k_t - (1 - \delta)k_{t-1}) + \delta^b K_{t-1}/\pi$

Housing Market Equilibrium:  $h_t = 1$

### 3.7 Calibration

We set the rural patient household discount rate at 0.9902 to reflect a steady state interest rate of 4 per cent per annum. The impatient households and entrepreneur discount factor is set at 0.975, each. The share of patient labor and impatient labor in firm output is set at 0.5. The price incentive/waiver provided by the BCAs to impatient households is fixed at an average of 6 per cent of the loan outstanding to reflect a mark-up of 5 percent over the policy rate at which BCAs sell the recovered loan to the banks. The default penalty parameter on the impatient household is set at 9.032 in line with the difference between the price incentive provided to induce repayment and the adjusted gross interest rate payable on the loan.

The average cost of incurring bank deposits is fixed at 0.3048 to reflect a deposit to GDP ratio of 0.41 and consumption of patient household to GDP ratio of 0.5. For the banking correspondent agent, no guidance is available in the literature. The mark-ups in BCA retailing based on market data available on BCA business. According to sources like 'Microsave', it costs Rs.15 per transaction for opening a deposit account, while the average revenue banking correspondents receive from banks per account opened is Rs.20. Thus on average, there is a 33 per cent mark up over the cost price. So we set the mark up in deposit collection market at 1.33 to reflect an elasticity of BCA deposit substitution of 4.03. The mark-up on loan disbursement services is fixed at 1.2305 so as to reflect a elasticity of BCA loan substitution at 5.338.

### 3.8 Results

I first analyze the impact of shocks which are unprecedented and specific to this paper - positive shocks to disutility attached to bank deposits and stochastic shocks to elasticity of substitution of deposits, loans and loan collection by banking correspondent agents. This is followed by a detailed discussion of more conventional shocks viz., monetary policy, technology shock and macro-prudential shock.

### 3.8.1 Unconventional Shocks

Interpreting the Euler equation, a unit standard deviation shock to disutility implies that a patient household will have to incur a higher sacrifice in period  $t$  by saving through bank deposits not only in terms of utility lost from consumption but also due to negative externalities attached to commuting to the bank, waiting time, understanding complex bank mechanisms and sundry others. To compensate the economic agent for the higher sacrifice, the bank ends up paying higher deposit interest rate in period  $t+1$  to retain consumer interest in bank saving products which in turn raises the funding cost for the bank. A shock to disutility from bank deposits contemporaneously reduces total consumption, deposits and total loans. While loans to firms decline, although loans to impatient households decline on impact but rise subsequently. In this respect, our results complement the results from Norris et al (2015). In a model with heterogeneous agents distinguished by wealth and talent, Norris et al (2015) have found that greater financial inclusion (decline in  $\varepsilon^d$ ) leads to more efficient allocation of funds to talented entrepreneurs and the ensuing efficient financial contracts limit the waste of financial frictions leading to higher GDP. There is an across the board rise in interest rates and non-performing assets. Bank offer higher rates to BCAs to induce better efforts to recover loans from the households. Capital accumulation and investment decline permanently and rental rate of capital surge. Bank profits rise as deposit outgo declines but later profits fall as decline in deposits is offset by decline in loans at a rising deposit interest rate. Overall, rising disutility from bank deposits, which may be construed as an intensification of financial exclusion, amount to a contractionary impact on aggregate consumption, output and total credit in the banking system. It not only reduces the flow of financial capital to productive sector (firms) but also raises the cost of funds for banks as interest rates rise (Appendix Table B.3, B.4 and B.5).

A one standard deviation shock to mark up on loan disbursing BCA units adversely affects banks profits as a result of which banks respond by raising more capital and reducing credit exposure to the impatient household. However, loans now get diverted to the firms leading to higher capital accumulation, investment and output. Interest on loans decline across the board, while deposit

interest rates decline. As the higher mark up shock is leverage deluding, non-performing assets ratio declines improving overall banking stability (Appendix Table B.6 and B.7).

### **3.8.2 Conventional Shocks**

#### **3.8.2.1 Monetary Policy Shocks**

Lending rates to firms are even more persistent and rise gradually. A contractionary monetary policy leads to standard results like decline in wages, aggregate consumption, inflation and output. But while loans to firms decline on impact as a result of decline in present discounted value of collateral, the decline is more than compensated by the increase in loans to households raising total amount of loans disbursed in the financial system. This may be explained within the model. Higher interest rates encouraged higher deposit flow into the banking system leading to higher total loans. Increased uncollateralised credit flow to the households is thus a result of declining collateral value and abundant funds with the system. But non-performing assets are rising on account of the monetary policy shock (Appendix Table B.11, B.12 and B.13).

#### **3.8.2.2 Shocks to Credit Supply - Macro-prudential Policy Shocks**

A negative one standard deviation shock to LTV ratio has a contractionary impact on output, wages and savings. Deposits rise on impact but decline by the fifth period. Total consumption expenditure declines on impact but recovers and rises steadily soon after. Contractionary macro-prudential policy particularly affects loans supply to firms despite an increase in the value of collateral. Total loans disbursed increases in line with deposits until the fifth quarter but declines thereafter. Credit flow to the household sector rises on impact and permanently thereafter leading to a rise in non-performing assets for the bank. Borrowing needs for the household strengthens

with declining wages and declining interest rates encourage higher offtake of loans by the household. Bank profits, however, decline, indicating that the resource outflow due to deposit more than offsets the accrual from loans. Investment demand slackens and inflation also declines. In sum, negative macro-prudential shocks a la decline in LTV ratios is pro-inclusion at least from the borrowers side (Appendix Table B.14, B.15 and B.16).

### 3.8.2.3 Technology Shocks

Figure B:17, B:18 and B:19 presents the responses to a positive unit standard deviation technological shock,  $z_t^e$ . Incorporation of financial inclusion features into the model seems to have enhanced the endogenous propagation of technological shock as in Gerali et al (2009) as many of the real variables are displaying higher persistence *viz.*, consumption, deposits, wages and loans to impatient households exhibit hump shaped behaviour. Higher asset prices induce the entrepreneurs to demand higher loans from the banks and the latter divert their funds to more secure and collateralised sources. For a given level of penalty parameter, bank passes on the initial spike in deposit interest rates to rates charged on uncollateralised loans to impatient households. BCAs, in turn have to offer higher per centage relief to ensure the households are capable of returning the loans. For a given mark-up, this implies that BCAs demand a higher rate for recovery of loans from the banks (Appendix Table B.17, B.18 and B.19).

## 3.9 Alternate Model No. 1

A positive shock to loan rate mark-up on loans to impatient households leads to some interesting observations. A 100 basis point hike in mark-up rate raises interest rate charged on consumer

Table 3.3: **Calibrated Parameters**

<i>Parameter</i>	<i>Description</i>	<i>Value</i>
$\beta_r$	Discount factor for Patient Households	0.9902
$\beta_i$	Discount factor for Impatient Households	0.975
$\beta_e$	Discount factor for Entrepreneurs	0.975
$\theta_i$	Coefficient on Hhd non-pecuniary default penalty	9.032
$\alpha$	Share of Patient Labor in Total Output	0.5
$v$	Basel Capital to Risk Weighted Assets Ratio Norm	0.09
$k_d$	BCA Deposit Rate Adj. Cost	0.5
$k_b$	BCA Loan Delivery Adj. Cost	6
$k_{kb}$	Leverage Dev. Cost	10
$k_f$	BCA Loan Collector Adj. Cost	10
$i_p$	price indexation	0.5
$\phi_p$	Weight assigned to Inflation in MP Equation	1.8
$\phi_y$	Weight assigned to Output in MP Equation	0.2
$\phi_r$	Weight assigned to Interest Rate in MP Equation	0.75
$\bar{f}$	Steady State repayment Rate of Hhd	0.95
$\bar{s}$	LTV ratio	0.72

loans by 50 basis points instantly. Higher mark-up motivates increased labor supply by banking correspondent agents (BCAs) and because of the linear technology connecting BCA labor supply to repayment rates, there is one to one rise in repayment rates (or decline in default rates). Loan offtake by impatient households rise but by a small margin after a within the quarter decline. Banking correspondent agents familiarisation with loan receiving households reduces the problem of adverse selection and enables them to be involved with the proper end-use of the loan and devise methods for loan recovery in sync with the household. Bank capital, however, declines and offsets an initial zero impact on aggregate loans resulting in a divergence of actual capital asset ratios from the norm and raising the marginal cost of technology. The resulting increase in credit spreads, however, causes banks to reduce interest rates charged to BCAs because of an expected rise in repayment rates. The banks, however, pass on the rise in cost of higher leverage to its other set of consumers, the entrepreneurs. Banks charge higher interest rates to firms which peaks only in the 5th quarter. Credit demand by firms rise initially which also leads to concomitant rise in asset values in the face of declining loan to value ratios. But demand declines subsequently as



interest rates start rising and loan to value ratios continue to decline.

### **3.9.1 Productivity Shock to BCAs**

The repayment rate is under the influence of two exogenous stochastic processes - technological shock ( $z_t^e$ ) and productivity shock specific to BCAs ( $z_t^b$ ). A productivity shock to BCAs reduces loan off-take by impatient households. Total borrowing, aggregate consumption and asset prices decline. In other words, a positive productivity shock to BCAs has a 'Leverage deluding' and an overall moderating impact on aggregate demand. On the other hand, technological shock tends to raise total borrowings, loan to value ratios, wages and consumption and reduces default rates with an overall positive impact on aggregate demand. So a technological shock has a 'leverage inducing' effect on the economy.

### **3.10 Alternate Model No. 2**

In this model, I evaluate the impact of financial inclusion on banks with stronger performance indicators in terms of stability. The banks under consideration are Basel III compliant and maintain a net financial stability ratio (NFSR) of at least 1. This also provides us the leeway to assess the impact of more variants of macro-prudential policy viz., the weights on bank capital and commercial loans that constitute the NFSR.

Increasing weights on loans to entrepreneurs in the NFS ratio has a significant contractionary impact on the business cycle. Interest rates on loans to entrepreneurs rise leading to a decline in offtake of such loans, entrepreneurial consumption declines and output contracts. Profit maximising banks divert loans to impatient households to retain profits. Profits rise on impact and hence bank capital also rises in tandem. However, this policy is not stability inducing as NPA ratios rise as the banks have more household loans in its balance sheet with lower repayment rates. In sharp contrast, raising conventional risk weights on entrepreneurial loans has an expansionary effect on

business cycles. Despite a rise in interest rate on such loans, banks continue to supply credit to this sector. Loans to entrepreneurs generate higher returns than loans to households such that it is easy to raise capital with the higher profits generated and meet the regulatory requirement. With conventional capital adequacy requirements, the bank can raise loans to entrepreneurs despite rising weights and yet prevent the deviation of the capital to risk weighted assets ratio from the norm, by an offsetting decline in loans to households with lower repayment rates and relatively lower returns.

Rising weights on deposits in NFSR induces a deviation of the NFS ratio from the norm prompting profit maximising banks to raise loans to entrepreneurs to reduce deviation costs. Since, existing deposits earn a higher weightage under the new policy and bank profits are also rising by raising loans to entrepreneurial sector leading to a rise in bank capital, banks have less incentive to raise more deposits. Hence deposit rates are decline and consequently deposits also decline. Aggregate output and consumption increase and NPA ratios decline as banks divert their business towards the productive sector with assured returns. However, raising weights on deposits in NFSR has some unintended effects such as lowering loans to impatient households and the consequent decline in household consumption expenditure.

### **3.11 Long Run Analysis**

What are the long run implications of financial inclusion policy on financial and banking stability? Does financial inclusion of the erstwhile unbanked population lead to a secular improvement of systemic stability?

The results of general equilibrium models provides crucial evidence towards a possible nexus between financial inclusion and financial stability. The DSGE analysis suggests that financial inclusion in the form of higher loans to impatient households through banking correspondent agents (BCAs) reduces NPAs by accelerating the repayment rate of the households. The log-linear approximation of the commercial bank balance sheet after suitable algebraic manipulation substanti-

ates this claim

$$\hat{f}_t + \hat{b}_t^p + \frac{n\bar{p}a}{\bar{b}^p} n\hat{p}a_t = \frac{\bar{K}}{\bar{b}^p} \hat{k}_t$$

where  $f_t$  is the repayment rate,  $b_t^p$  is the performing loans,  $n\hat{p}a_t$  is the non-performing loans and  $k_t$  is the bank capital.  $\hat{\cdot}$  signifies the log deviation from the steady state and  $\bar{\cdot}$  represents steady state values of the respective variables. Positive shocks to loans or repayment rate in the event of higher financial inclusion leads to compensating changes in NPLs to avoid making dynamic adjustments to the regulatory capital which in turn is expensive because of the quadratic costs of deviation from the international norm of capital to risk weighted assets ratio (9 per cent as per Basel II) or the net stable funding ratio (of at least 1 under Basel III).

This discussion leads us into two analytical directions and related empirical examinations. One, is there a common stochastic trend that underlies the fluctuations in credit to the domestic sector, non-performing loans and bank provisions as suggested by general equilibrium models. We test this hypothesis by examining the cointegrating relationship between credit, non-performing loans and provisions made by banks. We find significant cointegrating relationship between the relevant variables in 24 of the 29 countries surveyed. Most countries implementing bank based financial inclusion measures exhibited cointegration among credit, NPLs and bank provisions and witnessed a decline NPLs following a shock to inclusion.

Two, can we identify more than one permanent shock that might be underlying the fluctuations in these variables? It is very likely that credit and non-performing loans (NPLs) respond to permanent shocks to productivity as demand for credit generally tends to be higher during output booms and increasing values of collateral during boom phases may also ensure that banks and financial institutions are more willing to lend during these phases. But apart from productivity shocks, credit is also likely to respond to financial inclusion policy shocks. The concept of finan-

cial inclusion might have been coined a decade ago, but the concept is thriving in letter and spirit since years. Commercial banks in India, for example, began concerted efforts towards connecting with the masses by eliminating moneylenders and intermediaries soon after independence in 1947. Since 1970s, banks have been following priority sector lending targets to ensure that adequate institutional credit flows to the vulnerable sectors of the economy. Under this policy 40 per cent of the total adjusted net bank credit of the commercial banks must be channelled to the priority sector which includes the agriculture sector, micro enterprises and weaker sections. In other words, financial inclusion is a part and parcel of the credit policy of developing countries. Given that financial inclusion is an integral part of credit policy, we hypothesise that credit is also likely to respond positively to cumulative effects of permanent shocks to inclusion. Non-performing loans, on the other hand, are more likely to decline with higher output periods and higher credit/inclusion but it also responds positively to cumulative effects of permanent shocks to asset quality. In a standard VAR model with manufacturing output to GDP ratio, share of credit to domestic sector in total credit and non-performing loans as a proportion of total credit, we impose three  $(n(n-1)/2)$  long run restrictions to identify these permanent shocks

1. Manufacturing output to total output responds to permanent shocks to productivity but do not respond to shocks to inclusion and shocks to asset quality in the long run. This assumption is in line with the popular literature. Blanchard and Quah (1989) and King et al (1991) found strong evidence that output responds to supply side disturbances in the long run.
2. Credit to domestic sectors do not respond to shocks to asset quality in the long run.

The VAR with long run restrictions produces mixed results. We do not find statistically significant evidence that non-performing loans decline in response to permanent inclusion shocks. Instead, we find that NPLs decline permanently in response to cumulative productivity shocks and the response is statistically significant from zero. The only exception is the case of Malta where inclusion shocks permanently depress NPLs, although the response is not statistically significant. In some instances like Malaysia and Philippines, we also find evidence that NPLs have significantly

and permanently risen following financial inclusion shocks.

The paper is divided into the following sections. Section 1 describes the data and data sources. Section 2 elaborates the unit root tests. Section 3 describes the Johanssen Cointegration tests, identifying restrictions tests and results and impulse response analysis under VECM. Section 4 illustrates the VAR with long run identification under instrumental variable method along with the results. Section 5 summarises the paper.

### **3.12 Data Source**

We collect quarterly data on credit to other domestic sectors as a proportion of total credit disbursed (HH), non-performing loans to total loans(NPL), regulatory Tier-1 capital as a ratio of risk weighted as a measure of bank provisions(TIER-1-Capital), return on assets (ROA), return on equity (ROE) and share of manufacturing in GDP for 27 countries. The sample size and period of analysis varies according to the country under discussion and is provided in Table 1. All data has been sourced from the Financial Soundness Indicators (FSI) and International Financial Statistics database of the IMF.

### **3.13 Unit Root Tests**

We follow the method illustrated in Bullard and Keating (1995) in conducting the unit root tests. We apply augmented Dickey-Fuller tests to check for unit roots in all the time series for each country. We run two sets of five regressions for each variable. The first five are run with a constant and 0,1,2,3 and 4 lags and the second set of regressions are run with a constant and a deterministic trend and 0,1,2,3 and 4 lags. The adjusted Box-Ljung Q test statistic is calculated for serial correlation of orders 1,2,3 and 4 in each regression. Beginning with the results with the maximum lag, we proceed sequentially reducing the lag length by one if the Q-statistics is not significant at the higher lag.

### 3.14 Cointegration

If financial stability is predominantly affected by financial inclusion, it is very likely that credit, non-performing assets and bank provisions would share a long term cointegrating relationship. To test for all possible relationships, we divide the related variables into two blocks. In the first block, we test whether financial inclusion shock/credit shock is transmitted to non-performing loans and bank provisions.

The transmission channels are tested using a vector error correction model as relations are expected to follow a short term dynamics around possible stable long run equilibrium path. The specification are tested by changing the recursive order to ensure the system is not sensitive to a particular ordering.

The next step is to examine the co-integration properties of the set of variables for modelling them in VECM framework. The test statistics ( $\lambda_{Trace}, \lambda_{Max}$ ) for testing null hypothesis that the number of co-integrating vectors  $r = i$  against the alternative hypothesis that  $r \leq i$  are presented in the Appendix Table 1 and 2.

In the next step, we used a parsimonious vector error correction model for an nx1 vector of I(1) variables.

$$\Delta x_t = c + \Pi X_{t-1} + \Lambda \Delta x_{t-1} + e_t \quad (3.4)$$

The equilibrium properties of the above equation are characterized by the rank of  $\Pi$ . If the elements of  $z_t$  are I(1) and co-integrated,  $\Pi$  can be decomposed into two nxr full column rank matrices  $\alpha$  and  $\beta$ , where  $\Pi = \alpha\beta'$ , this implies that there exist  $r < n$  stationary linear combinations of  $z_t$ , such that  $\zeta_t = \beta' z_t$  distributed as I(0). The matrix of adjustment coefficients,  $\alpha$ , measures

Table 3.4: Cointegrating Vector

Country	Normalised Coefficients	Country	Normalised Coefficients
<b>Angola</b>	[1 1.926(5.749*) 7.546 (3.000*)]	<b>Papua N.G</b>	[1 -1.279 (-7.513*) 1.714 (7.705*)]
<b>Armenia</b>	[1 -1.162* (-6.930*) -1.153 (-7.309*)]	<b>Poland</b>	[1 4.052 (3.986*) 2.704 (1.798*)]
<b>Bosnia</b>	[1 -0.105 (-3.831*) 0.795 (3.443*)]	<b>South Africa</b>	[1 0.459 (8.402*) 0.737 (2.656*)]
<b>Brazil</b>	[1 0.566 (5.742*) -0.624 (-4.103*)]	<b>Trinidad</b>	[1 -0.009 (-0.197) -1.558 (-12.346*)]
<b>India</b>	[1 0.012 (0.578) 0.841 (3.413*)]	<b>Uganda</b>	[1 0 14.323 (7.112*)]
<b>Kazakhstan</b>	[1 0 2.105(6.968*)]	<b>Ukraine</b>	[1 0.128 (7.535*) 0.132 (2.980*)]
<b>Kenya</b>	[1 -0.052(-0.916*) -0.459 (-1.368)]	<b>Turkey</b>	[1 0 -1.222 (78.913*)]
<b>Lesotho</b>	[1 -5.561 (-3.075*) 10.028 (1.607)]	<b>Panama</b>	[1 -0.071 (-0.547) -1.952 (-4.745*)]
<b>Lithuania</b>	[1 0 0.073 (1,049*)]	<b>Nicaragua</b>	[1 -0.063 (-1.165) 1.099 (3.055*)]
<b>Malaysia</b>	[1 -0.009 (-0.546) 0.017 (0.180)]	<b>Mauritius</b>	[1 -0.003 (-0.027*) -2.461 (-3.437*)]
<b>Malta</b>	[1 -0.252 (-4.017*) 0.001 (0.008*)]	<b>Hungary</b>	[1 0.089 (1.498) -0.555 (-1.751)]
<b>Peru</b>	[1 0 -0.876 (-3.887*)]	<b>Romania</b>	[1 0 -0.306 (-4.844*)]

t-statistics in ()

how strongly deviations from the long-run equilibrium,  $\zeta_t$ , feed back into the system (Das and Manna, 2009).

The normalised coefficients of the cointegrating vector are produced in Table 1 below. The financial inclusion channel cointegration result shows that credit to domestic sector is strongly coupled with non-performing loans and is significantly contractionary in the long run with respect to Angola, Brazil, Poland, South Africa and Ukraine. The sobering impact on NPLs also prompts banks to adjust regulatory Tier 1 capital downwards, the only exception being Brazil where provisions rise even with a decline in NPLs

### 3.14.1 Identifying Restrictions

We test for identifying restrictions on the cointegrating vector and the adjustment coefficients of the error correction equation by setting up a likelihood ratio test statistic. There are several possible restrictions: restrictions on the rank of the long run matrix, restriction on the long run cointegrating vector, restriction on the short run dynamic coefficients and restrictions on loading parameters. However, it is difficult to apply all of them given the limitations of the sample size as the interaction of dynamic and long run parameters has a profound impact on the size and power of the tests. So, we apply two types of tests. One, we test for normalisation of coefficient with respect to the dependant variable in the long run cointegrating vector  $\beta$  matrix with the null hypothesis

$$H_0 : B(i, j) = 1$$

Two, we also test for the significance of the adjustment coefficients  $A(i, j)$  with respect to the error correction terms pertaining to each equation.

$$H_0 : A(i, j) = 0$$

The results of these tests are reported under Table 2. The results of the constrained vector error correction model is produced in Table 3.



Table 3.5: P-values with respect to LR Test of Identifying Restrictions

	$B(1,1)=1, A(1,1)=0$			$B(1,1)=1, A(2,1)=0$			$B(1,1)=1, A(3,1)=0$		
Angola	0.581	0.000	0.449						
armenia	0.025	0.000	0.934						
bosnia	0.147	0.002	0.004						
brazil	0.283	0.000	0.857						
india	0.018	0.020	0.000						
kenya	0.000	0.256	0.272						
lesotho	0.328	0.016	0.014						
malaysia	0.316	0.000	0.087						
malta	0.007	0.000	0.372						
mauritius	0.064	0.628	0.145						
nicaragua	0.050	0.044	0.929						
panama	0.071	0.060	0.013						
Papua NG	0.193	0.000	0.677						
poland	0.014	0.000	0.455						
south africa	0.029	0.000	0.168						
trinidad	0.631	0.000	0.000						
Ukraine	0.907	0.015	0.011						

Table 3.6: Adjustment Coefficients of EC Terms in Difference Equation (Constrained VECM) - (NPL, HH and Tier1<sub>capital</sub>)

Country	D(NPL_TL)	D(HH_TL)	D(TIER1_K)	Country	D(NPL_TL)	D(HH_TL)	D(TIER1_K)
<b>Angola</b>	-0.608 (-6.11) [0.62] 33.77	0 - [0.02] 0.32	0 - [0.02] 0.47	Malta	-0.11 (-5.19) [0.39] 27.50	0.02 (* -3.26) [0.16] 8.15	0 - [0.01] 0.61
<b>Armenia</b>	0 (-4.88) 0.62 33.77	-0.075 [NA] 0.02 0.32	0 [NA] 0.02 0.47	Mauritius	-0.032 (* -3.69) [0.54] 1.67	0 - [0.33] 0.71	0 - [0.66] 2.78
<b>Bosnia</b>	-0.048 (* -2.54) [0.66] 5.39	0 [NA] [0.21] 0.74	0.040747 (3.87) [0.52] 3.08	Nicaragua	-0.029 (* -1.61) [0.15] 1.19	0.008 -3.57 [0.23] 2.02	0 - [0.07] 0.53
<b>Brazil</b>	-0.326 (-5.87) 0.63 16.76	0 - 0.27 3.53	0 - 0.06 0.64	Papua N.G	-1.272 (* -3.55) [0.75] 5.19	0 - [0.42] 1.23	0 - [0.76] 5.51
<b>India</b>	-0.016 (-1.78431) [0.39] 0.66	-0.0059 (-1.76154) [0.48] 0.92	-0.00725 (-6.05409) [0.97] 30.94	Poland	-0.198 (* -6.08) [0.55] 35.49	-0.039 (* -2.78) [0.19] 7.21	0 - [0.02] 0.51
<b>Kenya</b>	-0.122 (-3.51) [0.53] 4.98	0.034413 -1.81 [0.17] 0.89	-0.05507 (-1.92) [0.21] 1.14	Ukraine	-0.824 (-3.14) [0.42] 1.22	0 [NA] [0.55] 2.09	-0.25356 (-2.71) [0.61] 2.69
<b>Lesotho</b>	-0.188 (-1.98) [0.61] 2.47	0 - [0.68] 3.39	0.288 (* -3.6) [0.87] 10.99	Trinidad	-0.241 (-5.37) [0.77] 22.05	0 [NA] [0.22] 1.93	0.186 (* 8.48) [0.89] 60.03
<b>Lithuania</b>	-0.324 (-11.09) [0.76] 90.92	0 - [0.00] 0.00	0 - [0.01] 0.19	Thailand	0 - [0.38] 1.69	0.014 (* 2.46) [0.41] 1.92	-0.015 (-2.37) [0.74] 8.02

() : t-statistics, [] : R\_square; F-Stat

### 3.14.2 Results

The remaining step of the exercise involves examining the sign and pattern of impulse responses of the relevant variables in reaction to one standard deviation cholesky shock to other relevant variables. Simple analytics show that out of the 29 countries surveyed for cointegration between credit to domestic sector, non-performing loans to total loans and bank provisions in the form of regulatory Tier-1 capital, 24 countries exhibited cointegration and a long run relationship between the relevant variables. No evidence of cointegration was found in Georgia, Ghana, Philippines, Tajikistan and Thailand.

In Panel A (Appendix Table B.20 and B.21), we present the impulse response results of 8 countries - Bosnia, Brazil, Hungary, Kazakhstan, Kenya, Romania, Trinidad and Ukraine - that exhibit cointegration and where non-performing loans declined permanently following an inclusion shock. Within this, the case of Bosnia and Ukraine are particularly interesting where credit explained 15.7 per cent and 10 per cent of the variations in NPLs in the same quarter, respectively. The per cent share of the variations explained by NPLs increased to 42 per cent by Q4 and further to 53 per cent and stabilised at that level by Q8 in the case of Ukraine. For Bosnia, the share increased to 21 per cent by Q4 and then stabilised at 26 per cent by Q8. Contrastingly, for Hungary and Kazakhstan, credit explained substantial variation in NPLs only in the longer run. In the case of Kazakhstan, variations in NPLs were largely explained by shocks to NPLs until Q5 and then the share of variations explained by credit jumped from 3.5 per cent in Q5 to 53 per cent by the end of Q10. The other interesting instance is presented by Brazil and Romania, both popular for their financial inclusion initiatives through the banking system. Although credit explained a considerable per centage of the variations in NPLs, a substantial share of the variations was also explained by shock to provisions. In the case of Brazil, credit and provisions explained 25 per cent and 35 per cent of the variations in NPLs, respectively by Q8, while in the case of Romania, credit and provisions explained 31 per cent and 26 per cent of the NPL variations by Q8, respectively.

In Panel B (Appendix Table B.22), we present the case of 5 countries - Angola, India, Lithuania, Poland and South Africa - where non-performing loans rose initially and then declined on average after 1-2 years. In India, non-performing loans rise initially but starts declining after Q4, while in Lithuania and Poland, the decline starts after Q8 despite an initial rise. In South Africa, the decline in NPLs sets in as early as Q3. Of particular interest is the case of India which has been implementing bank based financial inclusion measures for a considerable period of time. Credit explained 30 per cent of the variations in NPLs in the same quarter and this share increased to 38 per cent by Q8. For Angola and Poland, provisions and not credit explained the bulk of the variance in NPLs.

Panel C (Appendix Table B.23) records the results of 9 of the 24 countries where NPLs rise permanently following a one standard deviation shock to credit. This includes countries like Turkey and Peru where bank based financial inclusion is taking roots. In the case of Peru, credit explained 52 per cent of the variations in NPLs in the same quarter and this share graduates to 66 per cent by Q8 and stabilises permanently at that level. Variations in NPLs in Turkey, on the other hand, is largely explained by its own shocks. The case of Armenia is special as NPLs decline initially but start increasing from Q6 and then rise permanently.

### 3.15 VAR with Long Run Restrictions

We use the Shapiro and Watson (1988) and Fisher (2006) model of long run VAR with IV method for the estimation of long run multipliers.

Consider a structural VAR model

$$A_0 z_t = A(L) z_{t-1} + \varepsilon_t \quad (3.5)$$

where  $A_0$  is a matrix with ones in the diagonal,  $A(L)$  is a matrix of lag polynomials,  $z_t$  is a  $n \times 1$  vector with elements  $z_t = [mfg - gdp_t, \Delta h_t, \Delta npa_t]$  where  $mfg - gdp_t$  is the log of manufacturing to GDP ratio,  $h_t$  is the log of credit to domestic sector and  $npa_t$  is the log of ratio of non-performing

loans to total loans,  $\varepsilon_t$  is the vector of exogenous shocks with a variance covariance matrix given by  $E\varepsilon_t\varepsilon_t' = \Sigma$  where  $\Sigma$  is a diagonal matrix. The moving average representation of structural errors is given as

$$z_t = C(L)\varepsilon_t \quad (3.6)$$

where  $C(L) = [A_0 - A(L)]^{-1}$  or  $C(L)[A_0 - A(L)] = I$  is an identity matrix.

The first equation in the equation system (1) is given as

$$mfg.gdp_t = a_{yy}(L)mfg.gdp_{t-1} + a_{yh}(L)\Delta h_{t-1} + a_{yn}(L)\Delta npa_t + \varepsilon_{yt} \quad (3.7)$$

where  $a_{ij}(L)$ 's are the relevant lag polynomials. Equation implies that the contemporaneous effects of all non- $\varepsilon_{yt}$  shocks influence  $mfg.gdp_t$  through  $\Delta h_t$  and  $\Delta npa_t$ . But according to assumption 1, long run multipliers from these variables to the manufacturing GDP (mfg.gdp) are zero. As per Fisher (2006), imposing this restriction can be interpreted as imposition of unit root in each of the lag polynomials associated with  $\Delta h_t$  and  $\Delta npa_t$ . This in turn implies that  $a_{ij}$  for  $j=h, npa$  can be written as  $a_{yj} = \hat{a}_{yj}(L)(1 - L)$ . Substituting this into equation yields

$$mfg.gdp_t = a_{yy}(L)mfg.gdp_{t-1} + \hat{a}_{yh}(L)\Delta^2 h_t + \hat{a}_{yn}(L)\Delta^2 npa_t + \varepsilon_{yt} \quad (3.8)$$

Since disturbances to  $mfg.gdp_t$  affect the contemporaneous values of  $\Delta h_t$  and  $\Delta npa_t$ , although it is orthogonal to all variables dated  $t-1$  and earlier, this equation can be estimated by instrumental variable method using  $N$  lags of  $z_t$  as instruments. The residuals of this equation denoted as  $\hat{\varepsilon}_{yt}$  are stored to be used as instruments for estimation of later equations.

Assumption 2 implies that long run multipliers from  $\Delta npa_t$  to  $\Delta h_t$  are zero. This helps us to estimate equation sequentially with  $N$  lags of  $z_t$  and estimated residuals of equation 1 as instruments.

$$\Delta h_t = a_{hy}(L)\Delta h_{t-1} + a_{hy}(L)mfg.gdp_t + a_{hn}(L)\Delta npa_t + \varepsilon_{ht} \quad (3.9)$$

The third equation is now given as

$$\Delta npa_t = a_{nn}(L)\Delta npa_{t-1} + a_{ny}(L)mfg.gdp_t + a_{nh}(L)\Delta h_t + \varepsilon_{nt} \quad (3.10)$$

This equation is estimated using  $N$  lags of  $z_t$  and estimated residuals of the previous two equation as instruments.

### 3.15.1 Results

Next we turn to a discussion of impulse response functions. We report the accumulated impulse responses. Empirical evidence completely substantiates our first long run assumption. Manufacturing output rises and remains permanently higher following a permanent productivity shock. Inclusion shocks and asset quality shocks affect output only over a small horizon in line with our identifying assumption. This has been observed in all the countries surveyed. Similarly, permanent financial inclusion shocks raise credit to domestic sectors permanently and statistically significantly. In the case of Philippines, both productivity shocks and permanent shocks to inclusion lead to a permanent increase in credit. Productivity shocks explain 34.5 per cent and inclusion explain 62 per cent of the variations in credit by Q4 (Appendix Table B.24).

Appendix Table B.25 presents the case of Armenia where productivity shocks reduce NPLs permanently and significantly. Appendix Table B.26 shows the impulse responses for Malta where inclusion shocks lead to a permanent decline in NPLs but it is not statistically significant from zero. In the case of Brazil (Appendix Table B.28), productivity shocks explain a substantial percentage of the variations in NPLs over a period of time with a significant downward impact. By Q2, productivity shocks explain 41 per cent of the NPL variations and this share rises to 53 per cent by the end of one year. In Thailand (Appendix Table B.30), NPLs exhibit zero response to inclusion shocks until Q3 and rises after that, although not significantly.

Appendix Table B.24 and B.29 presents the case of Philippines and Malaysia, respectively, where inclusion shocks lead to a permanent and significant increase in NPLs. In Malaysia, inclusion shocks explain 12 per cent of the variations in NPLs in the same quarter which attains a peak of 14.4 per cent by Q3 and stays there permanently. In Philippines, inclusion shocks raise NPLs and explain 20 per cent of the variation in NPLs by Q1 which rises to 21.7 per cent by Q4.

### **3.16 Conclusion**

The paper develops a general equilibrium model to investigate how financial innovations in a bank based financial inclusion system affects the credit cycle with implications for bank's asset quality. To motivate financial inclusion, the banking correspondent agents are modelled in two alternative ways - one featuring BCAs as intermediaries between the bank and the household and two, featuring BCAs as business facilitators or loan advisors and planners involved through the lifecycle of the loan. The paper finds the model with BCAs as business facilitators scores over the model where BCAs are only intermediaries involved in cash-in and cash-out transactions in terms of its impact on financial stability and real variables. A rising cost of loan disbursal embedded in increasing mark-up on charges of loan disbursing BCAs though raises interest rates spontaneously, it has a limited impact on real variables. Instead, loans to households bounce back within a quarter, aggregate consumption, deposits, asset prices and loans to firms continue to rise, while NPA ratio declines. This is attributable to low default rates on loans which the BCAs ensure by managing the loan closely with the households. This imbibes confidence among both the households and banks about proper loan disbursal and recovery streamlining the credit cycle. In the first model, on the other hand, default rates are determined by exogenous processes and the BCAs provide price incentives to impatient households to recover the outstanding loan amount.

The paper also finds that a positive productivity shock to BCAs has a 'Leverage deluding' and an overall moderating impact on aggregate demand, while a technological shock has a 'leverage inducing' effect and tends to raise total borrowings, loan to value ratios, wages and consumption and reduces default rates with an overall positive impact on aggregate demand.

In terms of conventional shocks, monetary and macro-prudential policy tightening has the desired impact on all real variables. However, monetary policy shock exhibits enhanced propagation and most variables show higher persistence and hump shaped behaviour.

With respect to estimating the long run response of non-performing loans of banks to permanent credit shock which is a measure of financial inclusion, the empirical exercise builds on the premise that if financial inclusion is an integral part of credit policy in developing countries, credit and non-performing loans might be responding, possibly with opposite signs, to permanent shocks to inclusion, apart from cumulative productivity shocks in the long run. I test this hypothesis in two separate empirical exercises (i) Testing for cointegration between credit, non-performing loans and bank provisions, and (ii) VAR with long run restrictions using instrumental variables utilizing datasets of 28 developing/emerging market economies spanning Asia, Africa, Latin America and peripheral Europe. We particularly focus on those economies that have implemented bank based financial inclusion measures.

Cointegration results confirm the existence of a common stochastic trend between credit, NPLs and bank provisions in majority of the countries in the sample. NPLs are also found to decline permanently and statistically significantly in response to one standard deviation shock to credit in 14 countries. However, NPLs are also found to be rising significantly in 9 of the 24 countries that exhibited a cointegrating relationship. In VAR with long run identifying restrictions, we find that financial inclusion shocks have significantly and permanently raised credit to domestic sector in most countries in the sample. However, we did not find statistically significant evidence that non-performing loans decline in response to permanent inclusion shocks. Instead, the results of Armenia and Brazil confirm that NPLs decline permanently in response to cumulative productivity shocks and the response is statistically significant from zero. The only exception is the case of Malta where inclusion shocks permanently depress NPLs, although the response is not statistically significant. In some instances like Malaysia and Philippines, we also find evidence that NPLs have significantly and permanently risen following financial inclusion shocks.



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## **Appendix A**

### **Appendix to Chapter 2**

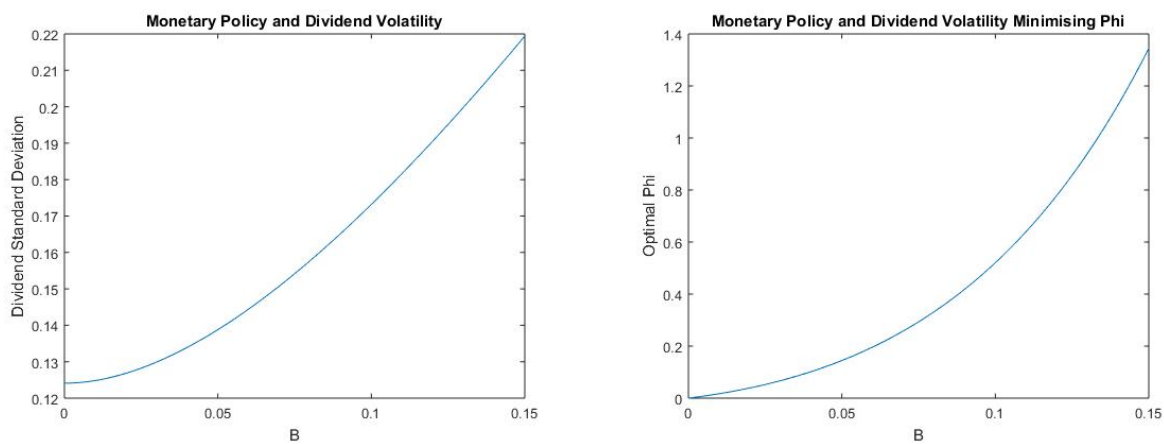


Figure A.1: Dividend Volatility and Monetary policy

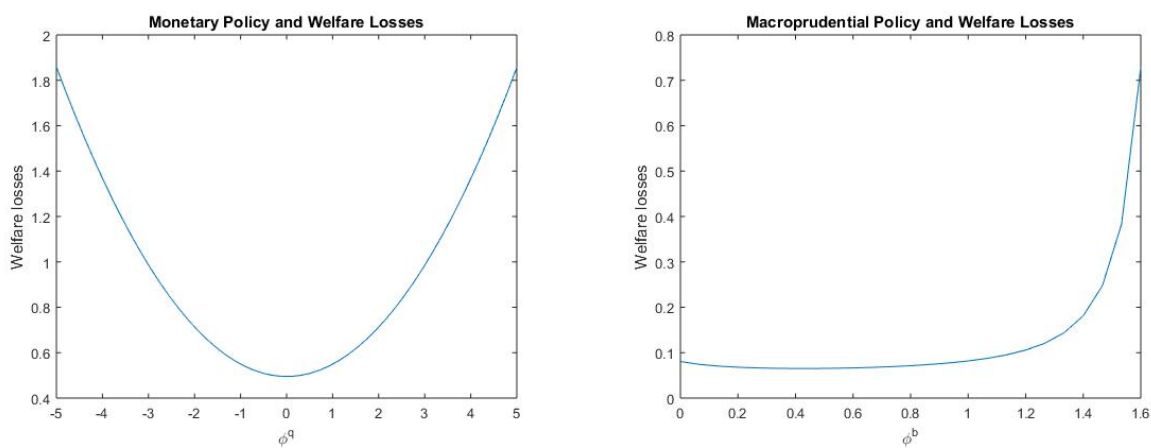


Figure A.2: Policies vs Welfare Losses

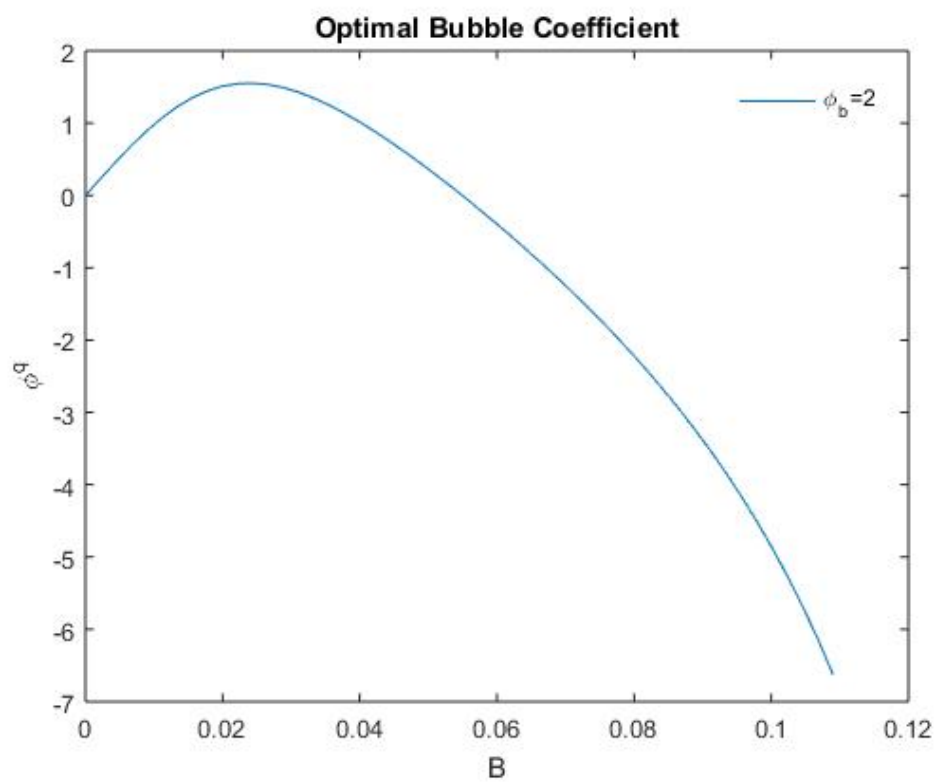


Figure A.3: Optimal Bubble Coefficient - Monetary Policy

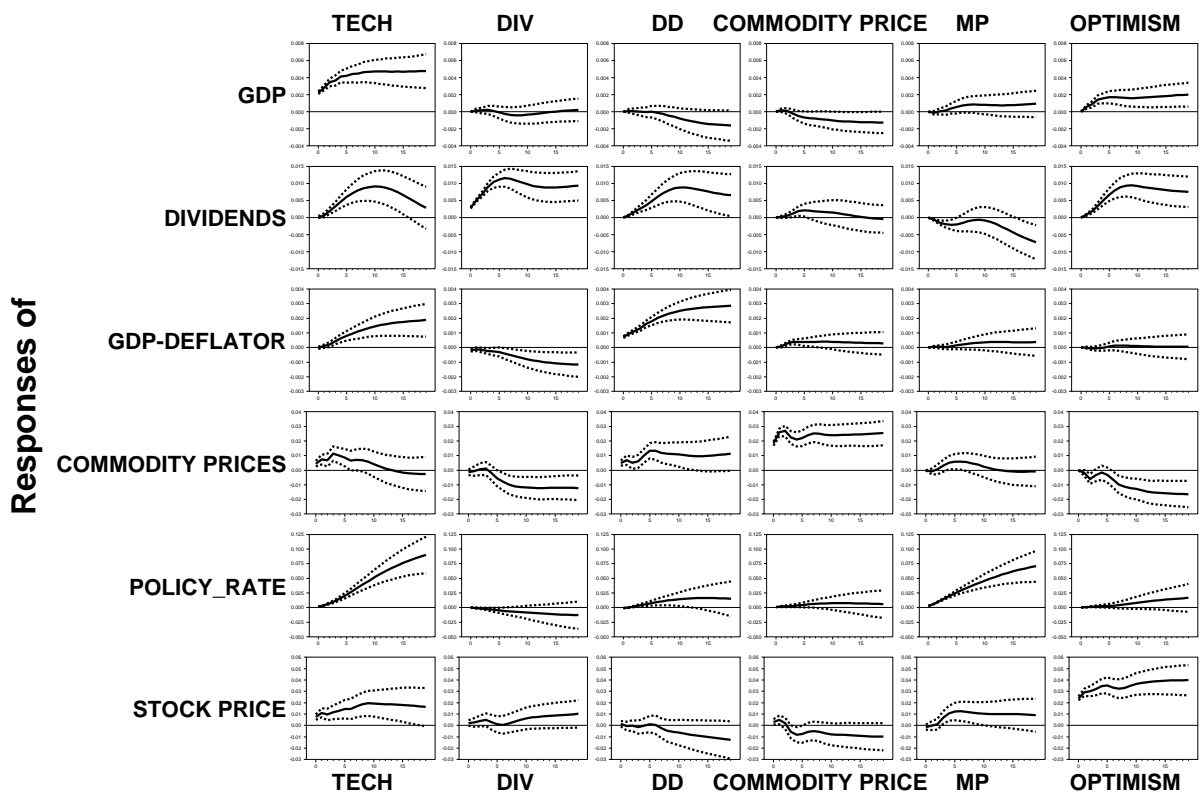
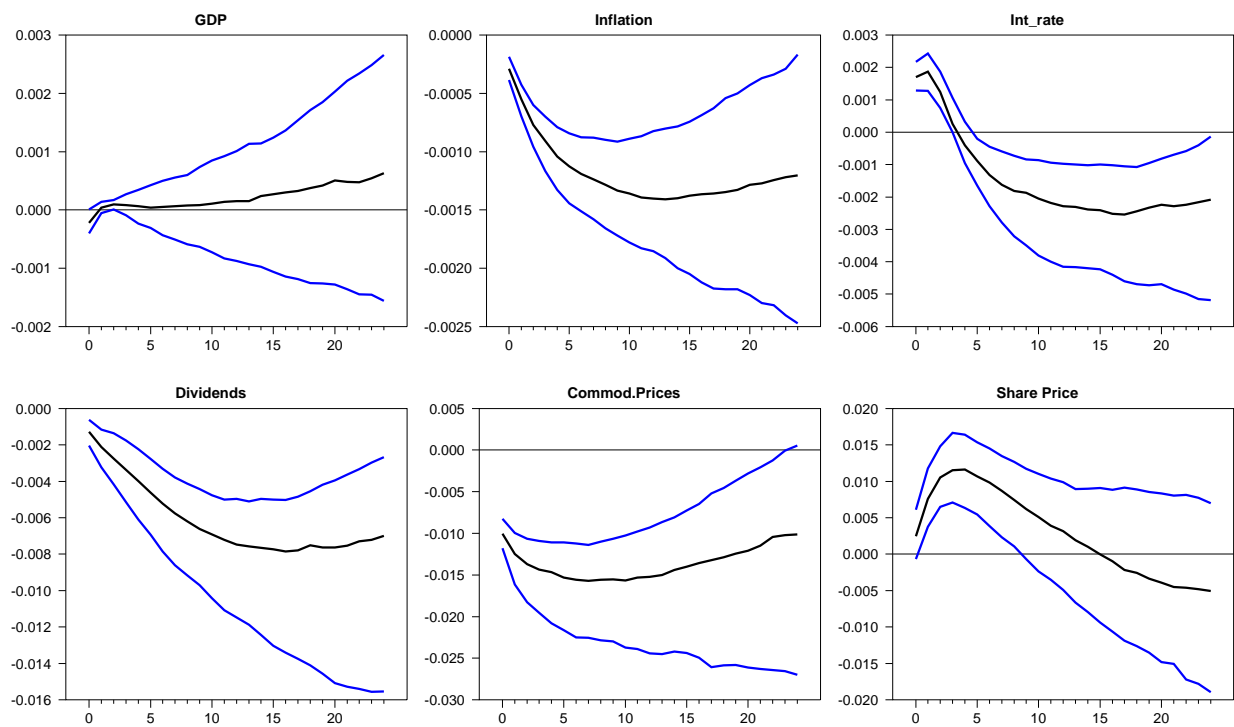


Figure A.4: Pure Monetary Policy Shock



Responses to Monetary

Figure A.5: SR-Monetary Policy Shock



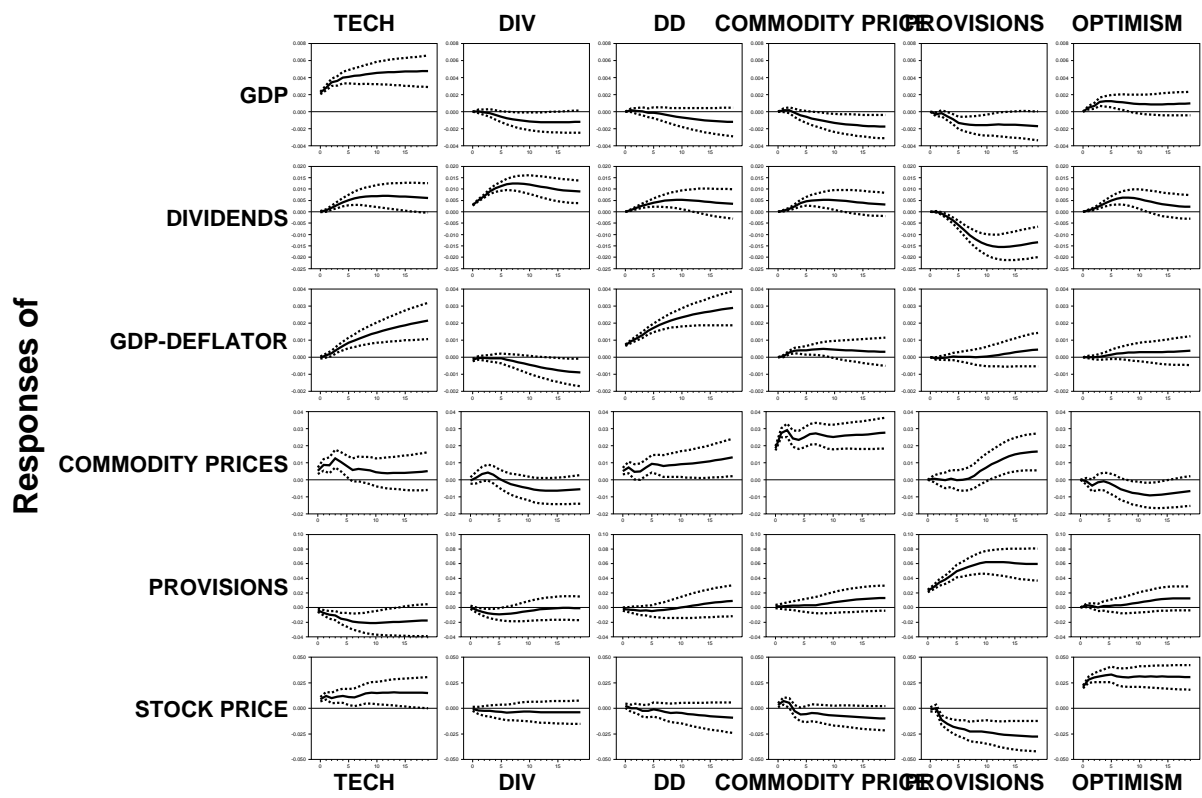
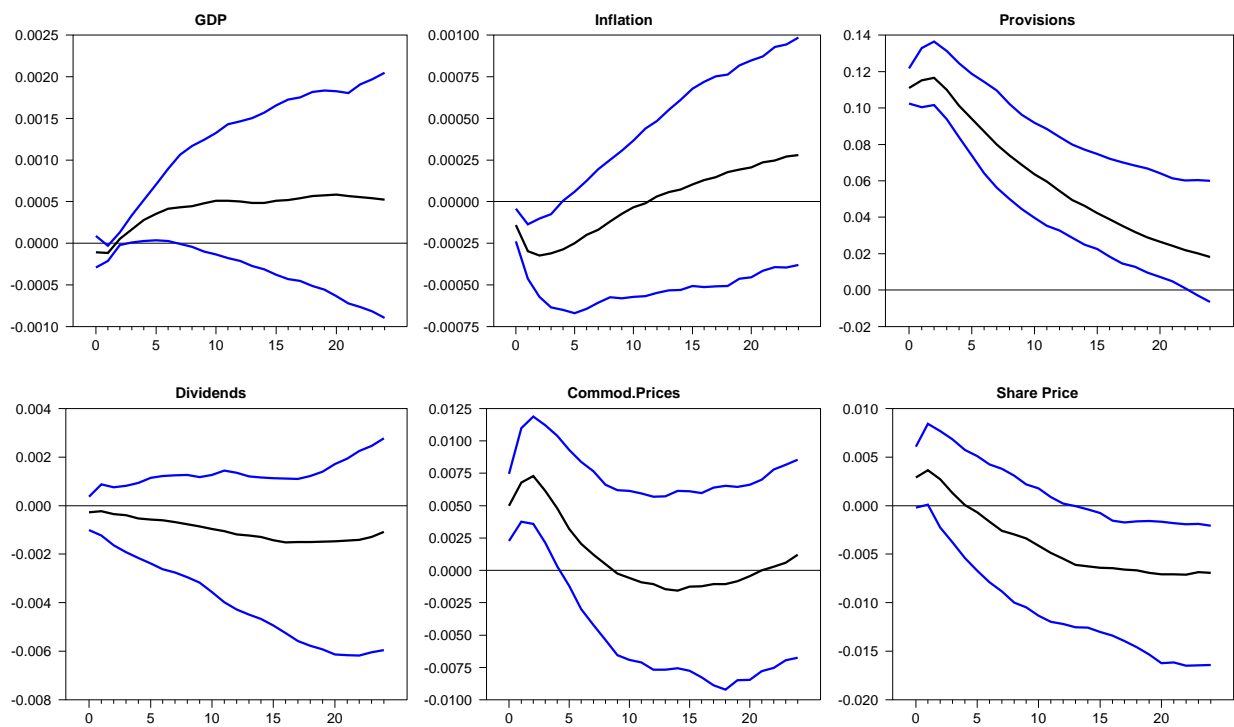


Figure A.6: Pure Provisions Shock



Responses to Provisions

Figure A.7: SR-Provisions Shock

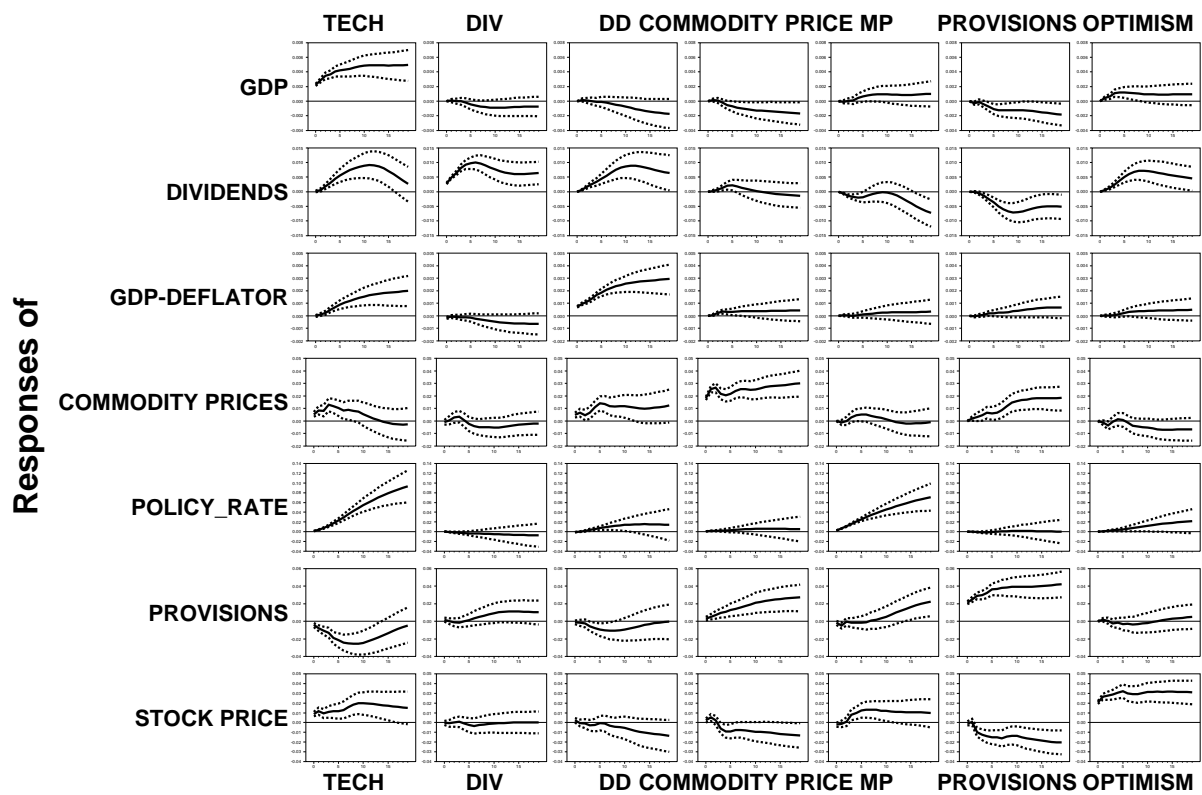
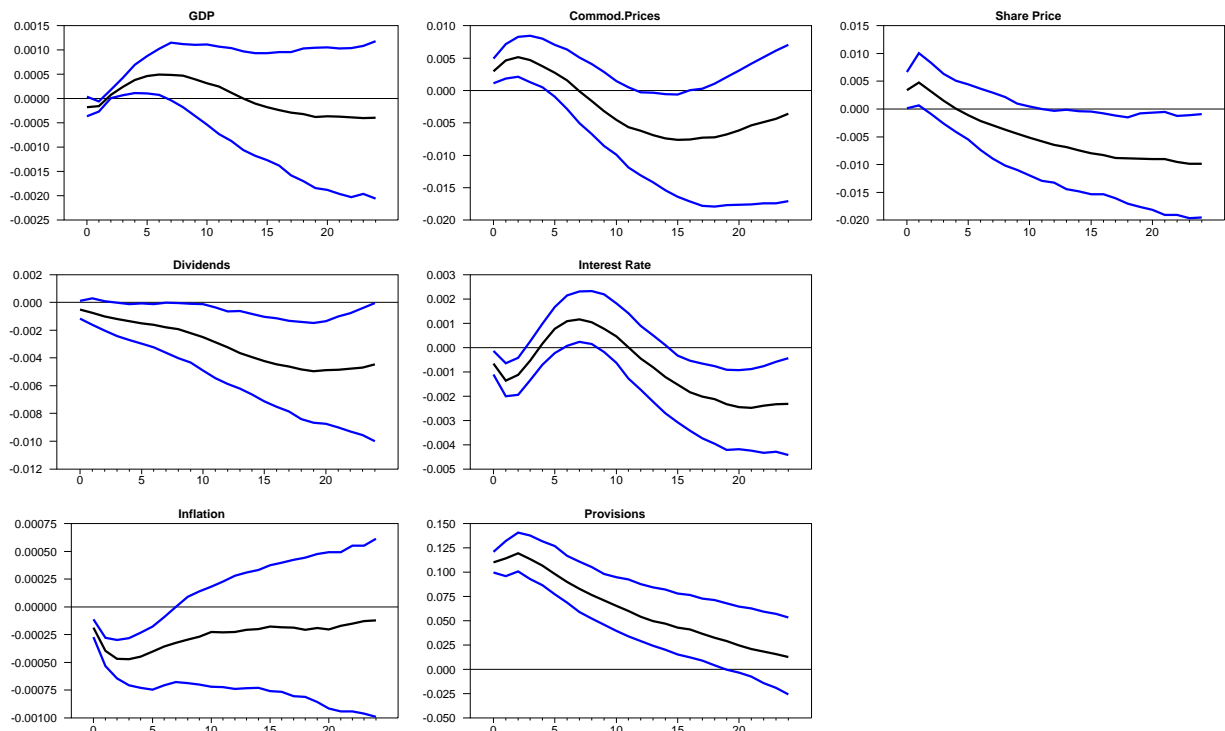


Figure A.8: Provisions Shock with Standard Taylor Rule



Responses to Provisions

Figure A.9: SR- Provisions Shock with Standard Taylor Rule

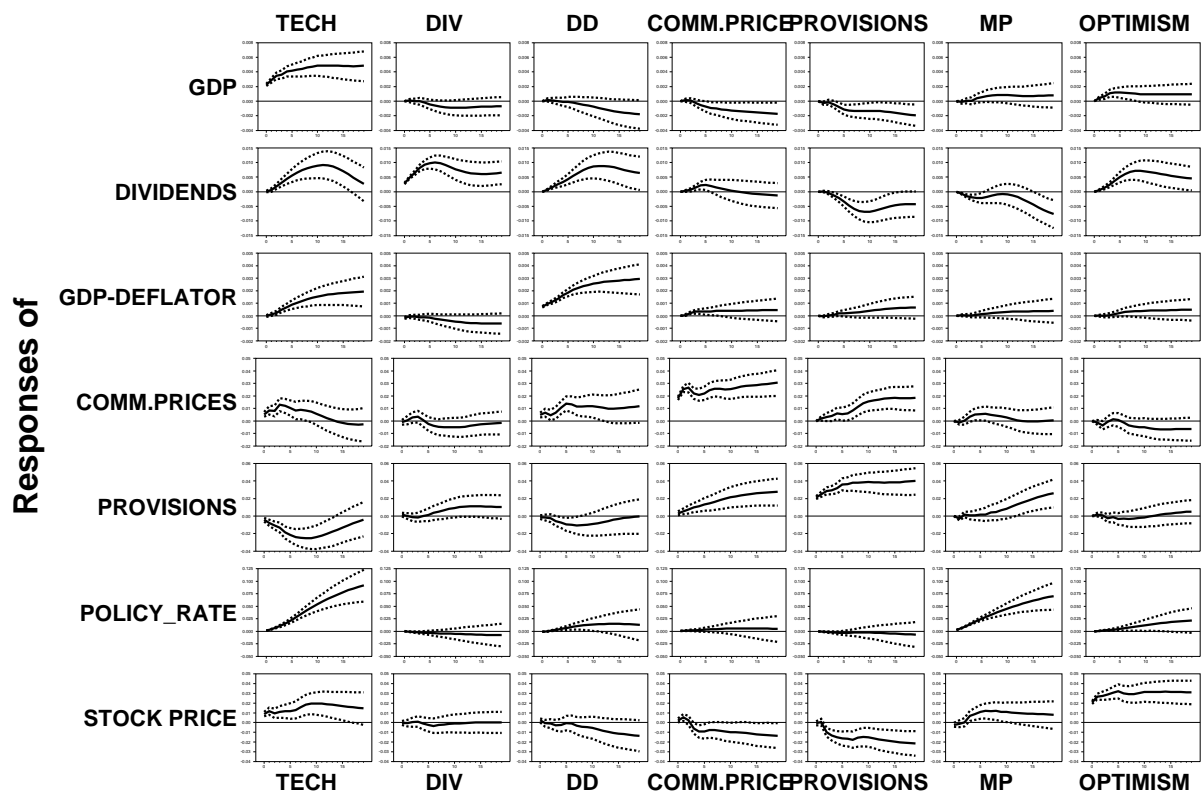
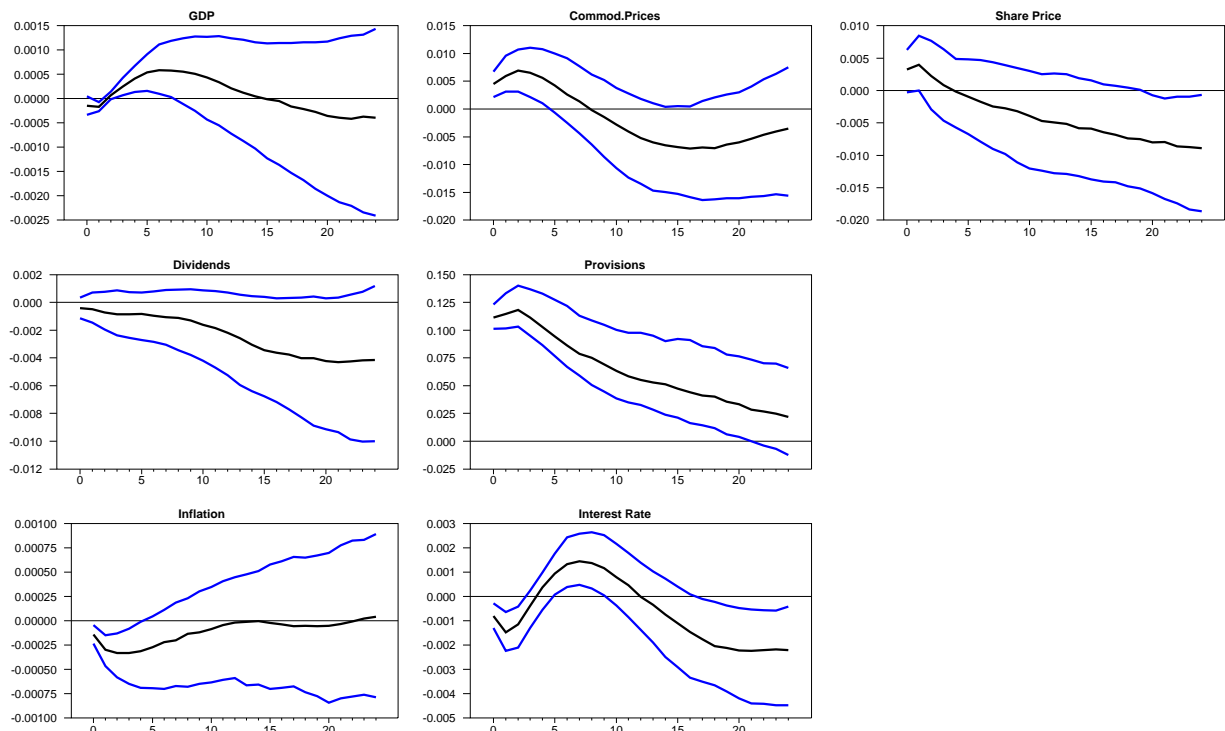


Figure A.10: Provisions Shock with Augmented Taylor Rule



Responses to Provisions

Figure A.11: SR- Provisions Shock with Augmented Taylor Rule

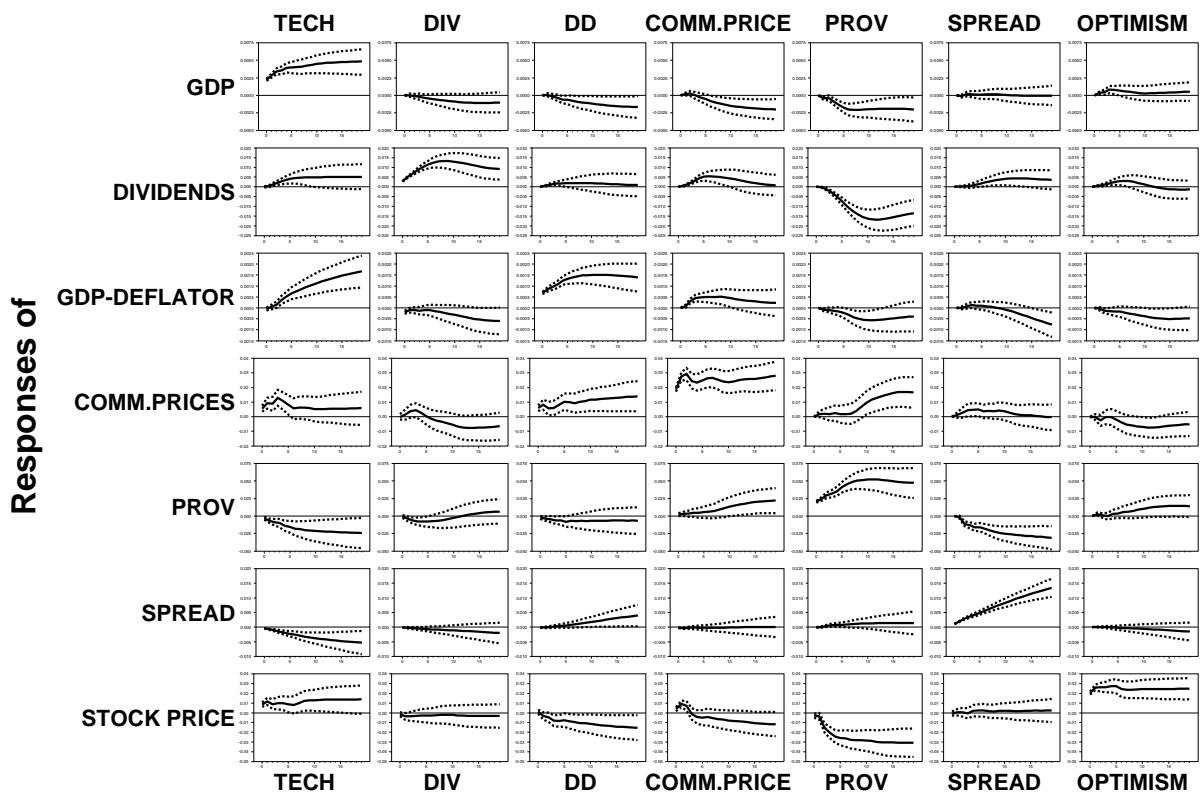


Figure A.12: Provisions Shock with Spreads

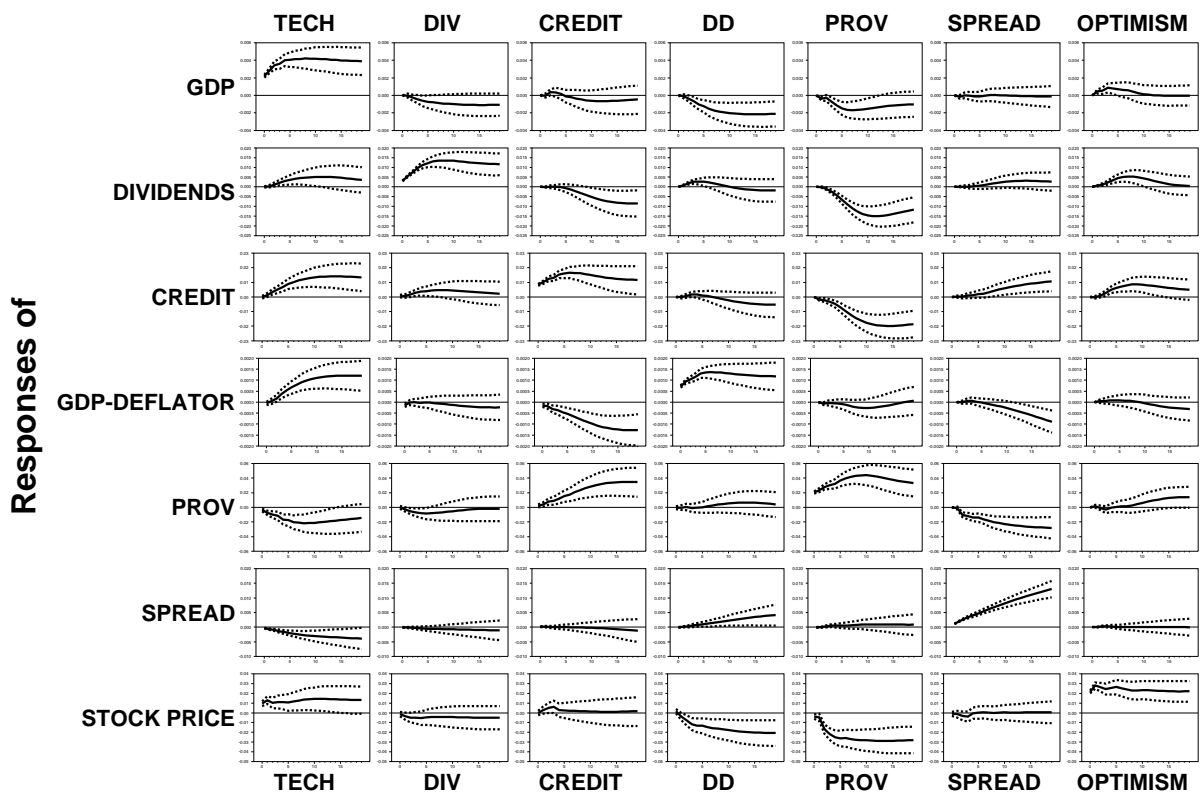
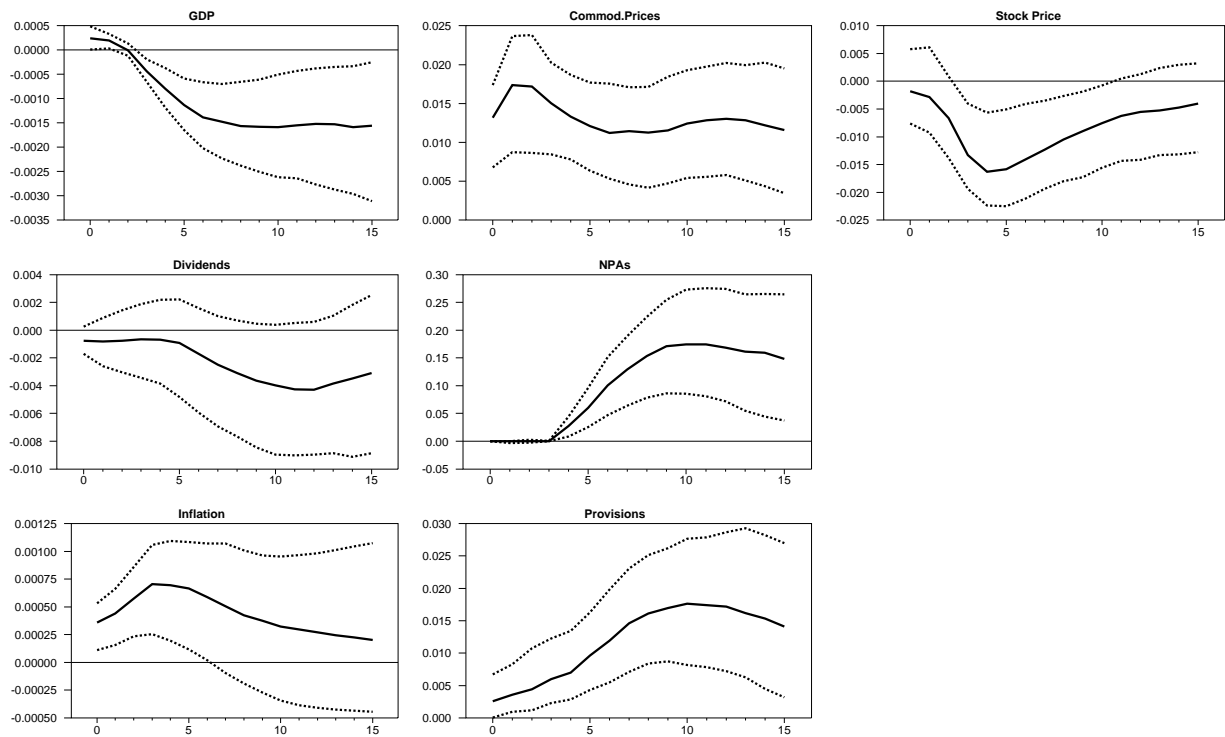


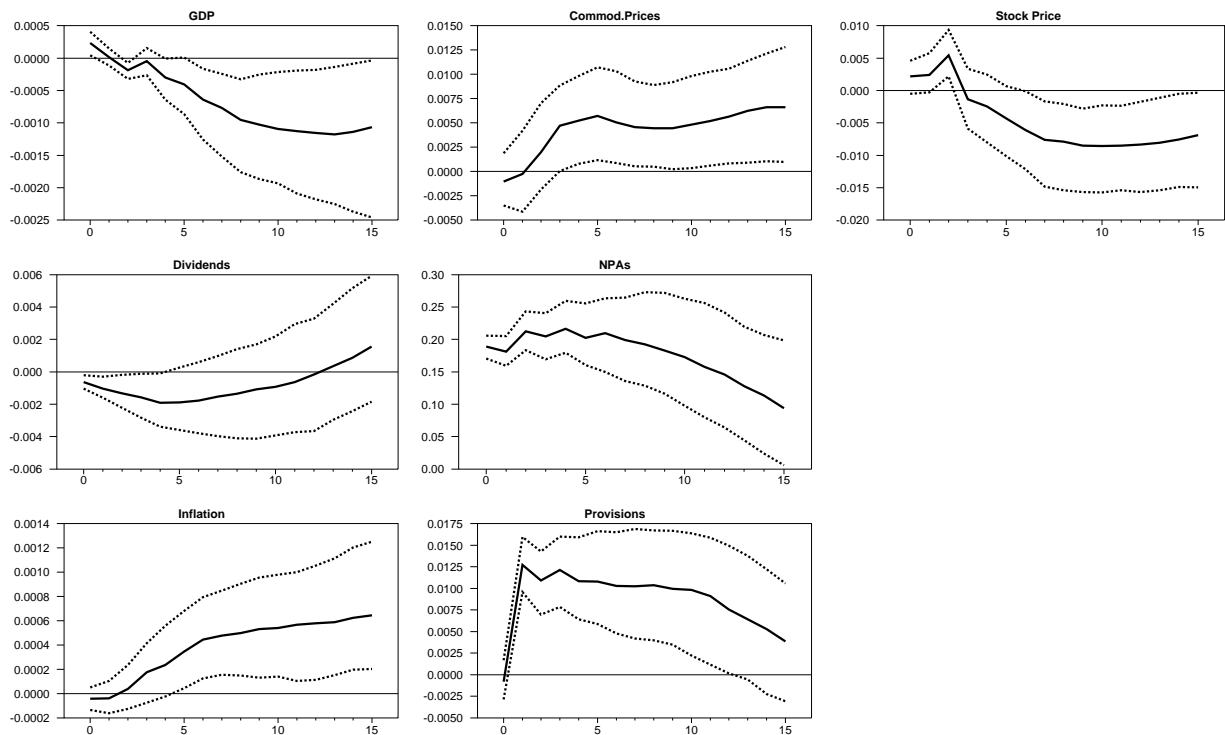
Figure A.13: Provisions Shock with Credit





Responses to Provisions

Figure A.14: Dynamic Provisioning Policy Shock



Responses to Asset\_Quality

Figure A.15: Asset Quality Shock

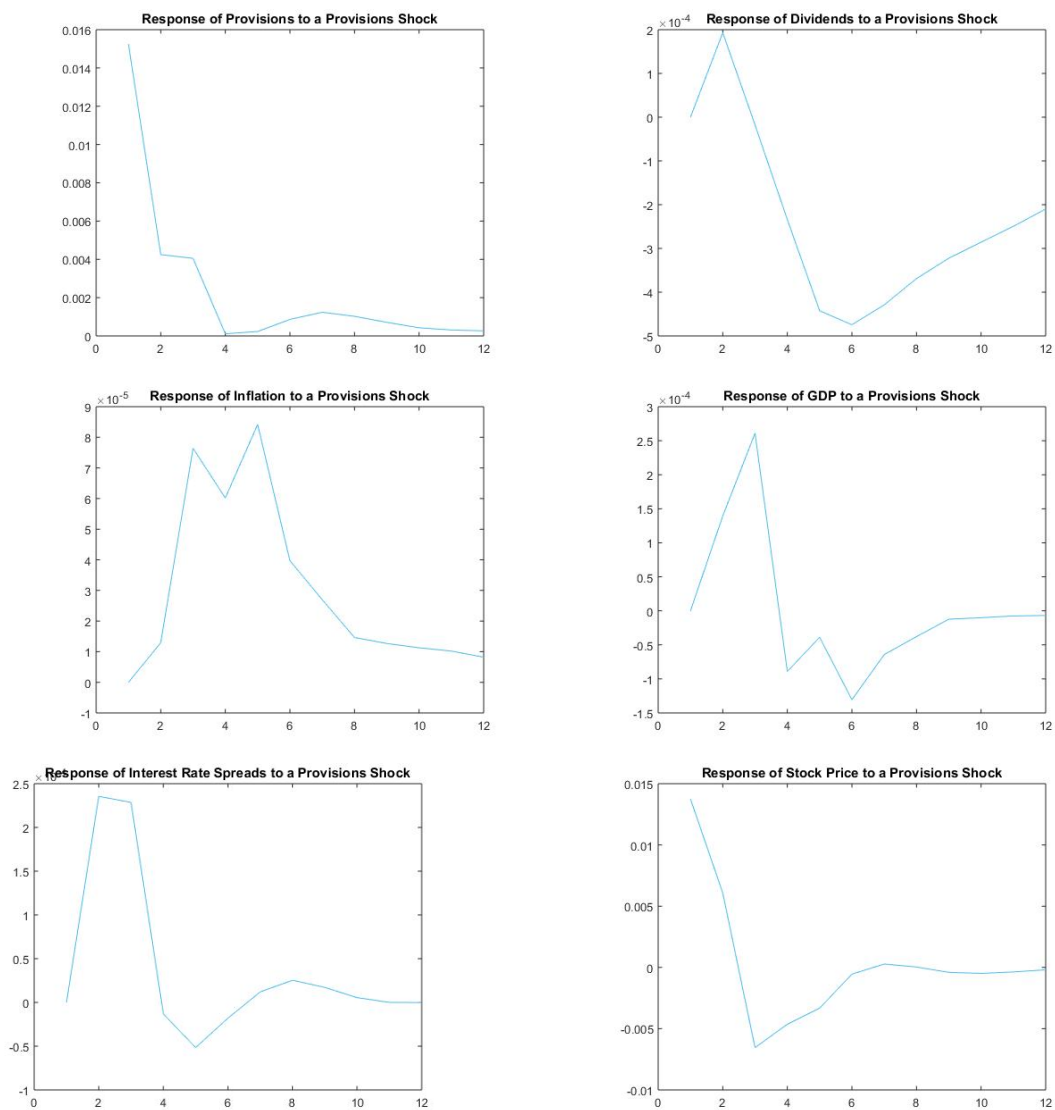


Figure A.16: AB-Specification-1:Response to Provisions Shock

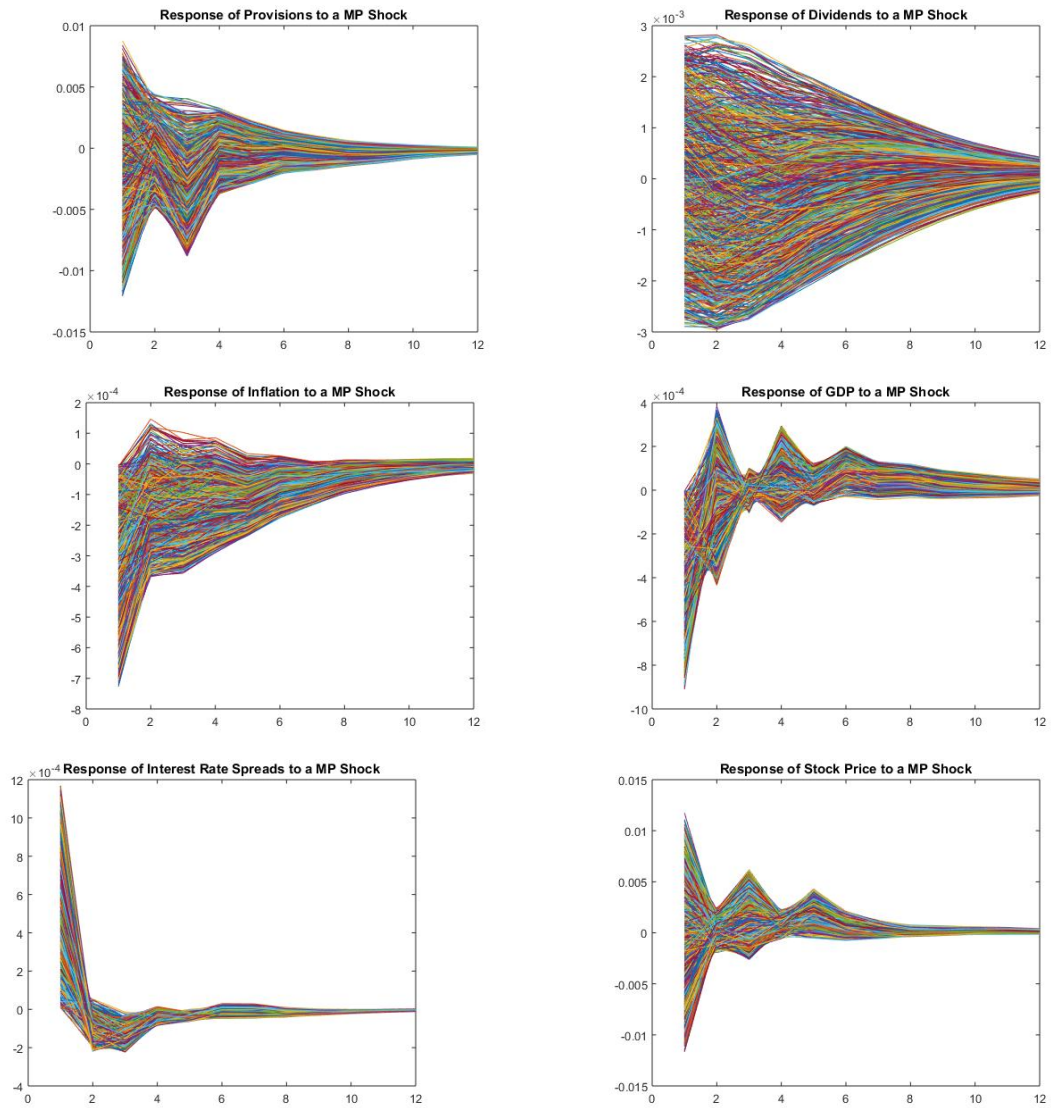


Figure A.17: AB-Specification-1:Response to Monetary Policy Shock

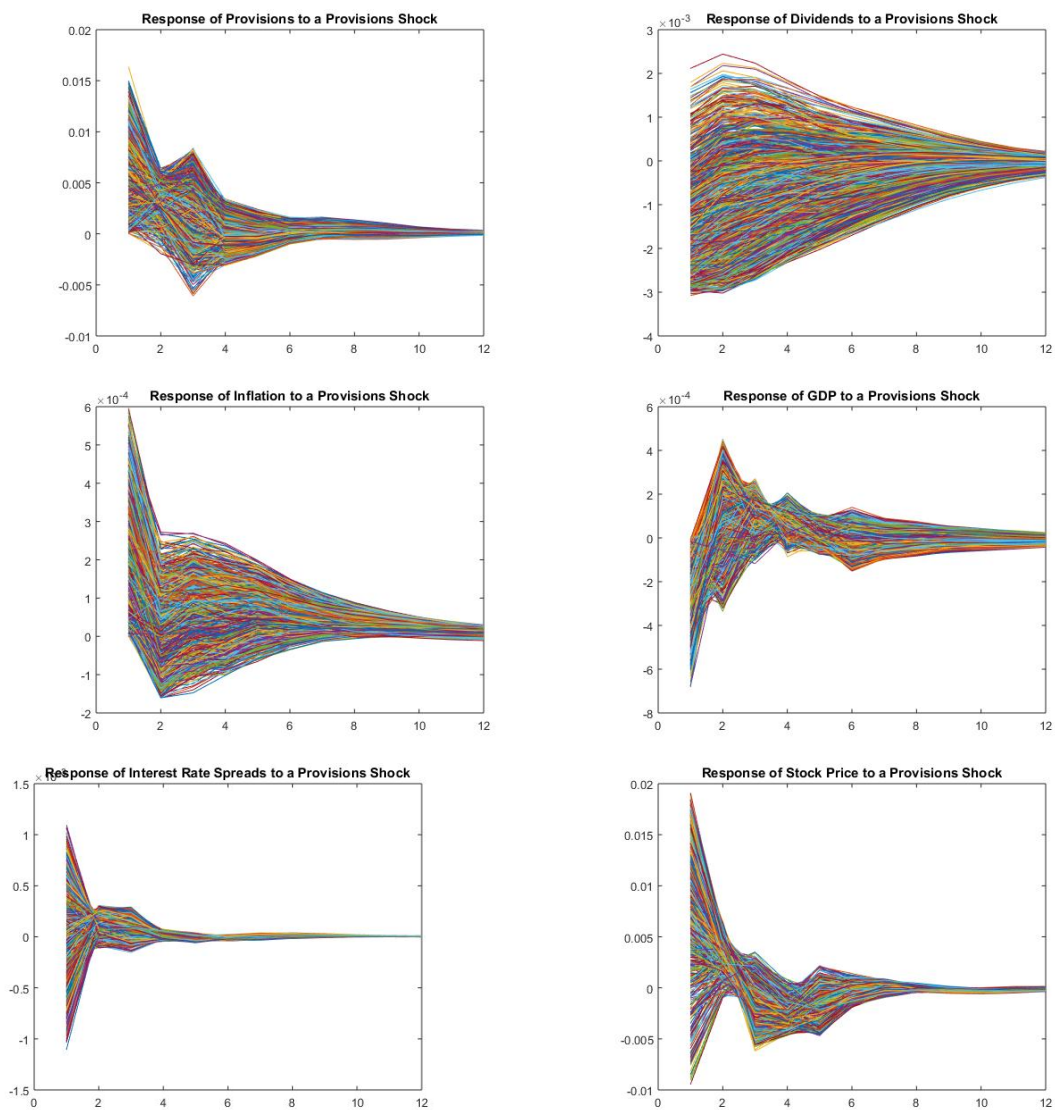


Figure A.18: AB-Specification-2:Response to Provisions Shock

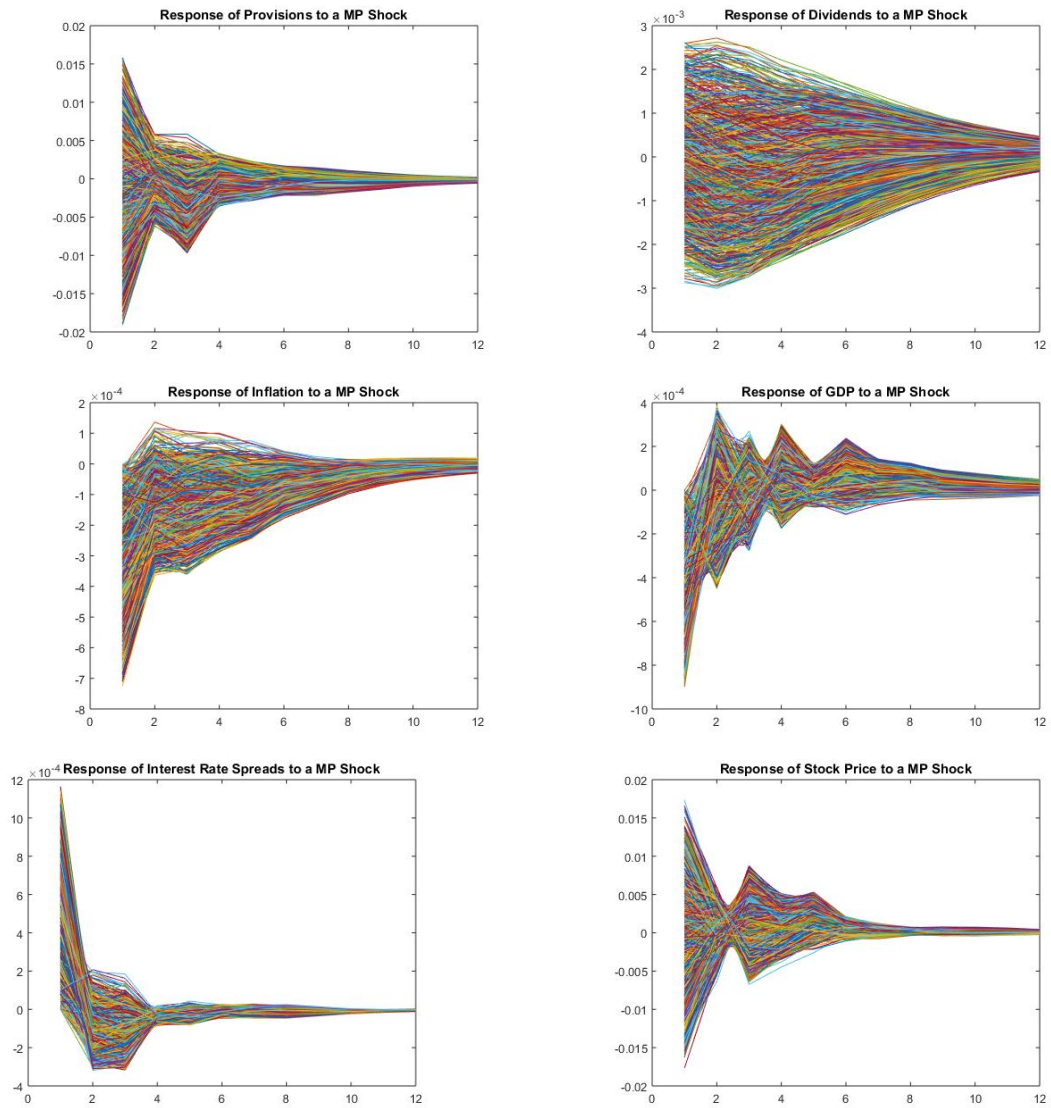


Figure A.19: AB-Specification-2:Response to Monetary Policy Shock

## **Appendix B**

### **Appendix to Chapter 3**

**Table B.1: Difference in Difference  
Estimates at Country Level - Part I**

	DID Estimates (FE)	DID Estimates (RE)
fi	-0.419** (0.17)	-0.398*** (0.14)
logcar	-0.149 (0.13)	-0.145 (0.11)
logpvt_credit_gdp	0.293*** (0.10)	0.0971 (0.07)
logm_lev	-0.0396 (0.06)	-0.0246 (0.06)
2001.year	-0.0941 (0.15)	-0.113 (0.15)
2002.year	-0.157 (0.14)	-0.168 (0.15)
2003.year	-0.385*** (0.15)	-0.398*** (0.15)
2004.year	-0.327 (0.22)	-0.344 (0.22)
2005.year	-0.807*** (0.15)	-0.774*** (0.15)
2006.year	-0.948*** (0.15)	-0.922*** (0.15)
2007.year	-1.126*** (0.15)	-1.070*** (0.15)
2008.year	-1.216*** (0.15)	-1.141*** (0.15)
2009.year	-0.959*** (0.15)	-0.876*** (0.15)
2010.year	-1.024*** (0.15)	-0.946*** (0.15)
2011.year	-1.111*** (0.15)	-1.028*** (0.15)
2012.year	-1.034*** (0.16)	-0.946*** (0.15)
2013.year	-0.972*** (0.16)	-0.876*** (0.16)
Constant	2.085*** (0.48)	2.734*** (0.42)
R-squared	0.341	
Number of country_id	56	56



Table B.2: **Difference in Difference  
Results - Country Level (Part 2)**

	Coef.	Std.Err	t	P> t	95 per. CI	
<b>log.rgdp</b>	-0.065	0.085	-0.760	0.450	-0.233	0.104
<b>log.rcredit</b>	-0.072	0.034	-2.080	0.039	-0.140	-0.004
<b>fi</b>	0.310	0.269	1.150	0.250	-0.221	0.841
<b>pr_31</b>						
2	-0.231	0.407	-0.570	0.571	-1.036	0.574
3	0.657	0.428	1.540	0.127	-0.189	1.504
4	0.914	0.435	2.100	0.037	0.055	1.773
<b>pr_32</b>						
2						
3	-0.559	0.375	-1.490	0.138	-1.299	0.181
4	-0.314	0.297	-1.060	0.292	-0.901	0.272
<b>pr_33</b>						
2	0.560	0.435	1.290	0.200	-0.299	1.420
3	0.130	0.345	0.380	0.706	-0.551	0.812
4	-0.294	0.284	-1.040	0.302	-0.855	0.267
<b>div_1</b>	0.158	0.081	1.950	0.053	-0.002	0.318
<b>spread</b>	0.008	0.021	0.360	0.720	-0.034	0.049
<b>lerner index</b>	-1.943	0.615	-3.160	0.002	-3.157	-0.728
<b>year</b>						
2001	-0.228	0.190	-1.200	0.231	-0.603	0.147
2002	-0.263	0.182	-1.450	0.150	-0.621	0.096
2003	-0.407	0.184	-2.210	0.029	-0.771	-0.043
2004	-0.505	0.186	-2.710	0.008	-0.873	-0.137
2005	-0.950	0.187	-5.090	0.000	-1.319	-0.581
2006	-1.157	0.192	-6.020	0.000	-1.536	-0.777
2007	-1.219	0.189	-6.450	0.000	-1.592	-0.846
2008	-1.191	0.189	-6.300	0.000	-1.564	-0.817
2009	-1.160	0.251	-4.620	0.000	-1.655	-0.664
2010	-1.138	0.207	-5.490	0.000	-1.547	-0.729
<b>_cons</b>	2.604	0.305	8.530	0.000	2.001	3.207

**Table B.3: Difference in Difference  
Estimates for NPAs - Bank Level (India)**

	DID Estimates India (FE)	DID Estimates India (RE)
fi	-0.184	-0.157
	-0.176	-0.159
logcrar	-0.729***	-0.666***
	-0.154	-0.146
logadv	-0.713***	-0.773***
	-0.191	-0.162
logint_inc	0.759***	0.620***
	-0.186	-0.161
2003.year	-0.323**	-0.286**
	-0.142	-0.144
2004.year	-0.645***	-0.569***
	-0.152	-0.15
2005.year	-0.844***	-0.757***
	-0.193	-0.186
2006.year	-1.208***	-1.083***
	-0.202	-0.189
2007.year	-1.325***	-1.154***
	-0.212	-0.188
2008.year	-1.233***	-0.559**
	-0.466	-0.233
2009.year	-1.036**	-0.337
	-0.477	-0.239
2010.year	-1.303**	-0.575**
	-0.505	-0.25
2011.year	-1.289**	-0.502**
	-0.537	-0.253
2012.year	-1.051*	-0.226
	-0.558	-0.255
Constant	4.185***	5.355***
	-1.202	-0.743
R-squared	0.381	
Number of bankn	71	71

Table B.4: Results of Johanssen Cointegration Test

Country	Hypothesis	Eigenvalue	Trace Statistic	Max Eigenvalue
<b>Angola</b>	None *	0.649	35.174*	24.093*
	At most 1	0.293	11.080	7.980
	At most 2	0.126	3.101	3.101
<b>Armenia</b>	None *	0.538	42.045*	33.193*
	At most 1	0.175	8.852	8.295
	At most 2	0.013	0.557	0.557
<b>Bosnia</b>	None *	0.537	41.659*	30.072*
	At most 1	0.256	11.587	11.540
	At most 2	0.001	0.046	0.046
<b>Brazil</b>	None *	0.478	41.414*	28.624*
	At most 1	0.214	12.790	10.574
	At most 2	0.049	2.216	2.216
<b>India</b>	None *	0.928	69.981*	55.285*
	At most 1	0.473	14.696	13.442
	At most 2	0.058	1.254	1.254
<b>Kazakhstan</b>	None *	0.671	56.348*	36.719*
	At most 1	0.382	19.629*	15.867*
	At most 2	0.108	3.762	3.762
<b>Kenya</b>	None *	0.462	37.813*	24.777*
	At most 1 *	0.206	13.036	9.251
	At most 2	0.090	3.785	3.785
<b>Lithuania</b>	None *	0.600	47.289*	26.597*
	At most 1	0.435	20.692*	16.565*
	At most 2	0.133	4.127*	4.127*
<b>Malaysia</b>	None *	0.548	46.039*	34.107*
	At most 1	0.192	11.932	9.171
	At most 2	0.062	2.761	2.761
<b>Malta</b>	None *	0.552	46.287*	36.167*
	At most 1	0.196	10.120	9.822
	At most 2	0.007	0.298	0.298
<b>Mauritius</b>	None *	0.561	34.380*	20.559
	At most 1 *	0.357	13.821	11.032
	At most 2	0.106	2.789	2.789
<b>Nicaragua</b>	None *	0.463	34.248*	20.518
	At most 1	0.243	13.729	9.202
	At most 2	0.128	4.528	4.528

\*': indicate significance level at 5%

Table B.5: Results of Johanssen Cointegration Test (contd...)

Country	Hypothesis	Eigenvalue	Trace Statistic	Max Eigenvalue
<b>Panama</b>	None *	0.455	38.813*	26.090*
	At most 1	0.190	12.723	9.063
	At most 2	0.082	3.660	3.660
<b>Papua N.G</b>	None *	0.557	26.792	23.605*
	At most 1	0.097	3.187	2.957
	At most 2	0.008	0.230	0.230
<b>Poland</b>	None *	0.600	37.235*	28.430*
	At most 1	0.218	8.805	7.640
	At most 2	0.037	1.165	1.165
<b>Ukraine</b>	None *	0.446	41.748*	23.595
	At most 1	0.260	18.153	12.064
	At most 2	0.141	6.089	6.089
<b>Uganda</b>	None *	0.619	61.090*	36.714*
	At most 1	0.449	24.376*	22.674*
	At most 2 *	0.044	1.702	1.702
<b>Trinidad</b>	None *	0.837	70.515*	59.843*
	At most 1 *	0.267	10.671	10.249
	At most 2	0.013	0.422	0.422
<b>South Africa</b>	None *	0.780	59.044*	46.976*
	At most 1 *	0.302	12.068	11.140
	At most 2	0.029	0.928	0.928
<b>Turkey</b>	None *	0.291	26.378*	13.3886
	At most 1 *	0.246	12.990*	11.00399
	At most 2	0.050	1.986	1.986
<b>Peru</b>	None *	0.860	66.407*	41.264*
	At most 1 *	0.603	25.143*	19.376*
	At most 2	0.240	5.767	5.767
<b>Romania</b>	None *	0.611	42.958*	23.630*
	At most 1 *	0.511	19.329*	17.888*
	At most 2	0.056	1.441	1.441
<b>Hungary</b>	None *	0.622	43.090*	27.265*
	At most 1 *	0.328	15.825	11.122
	At most 2	0.155	4.703	4.703

\*': indicate significance level at 5%

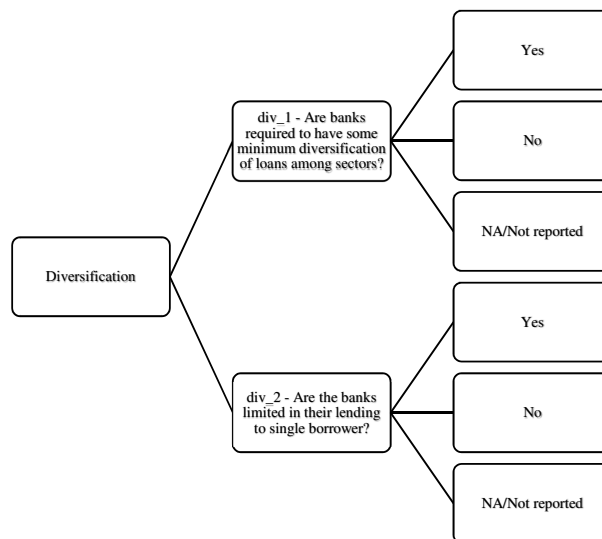


Figure B.1: **Categorical Variable used in Difference in Difference Estimation**

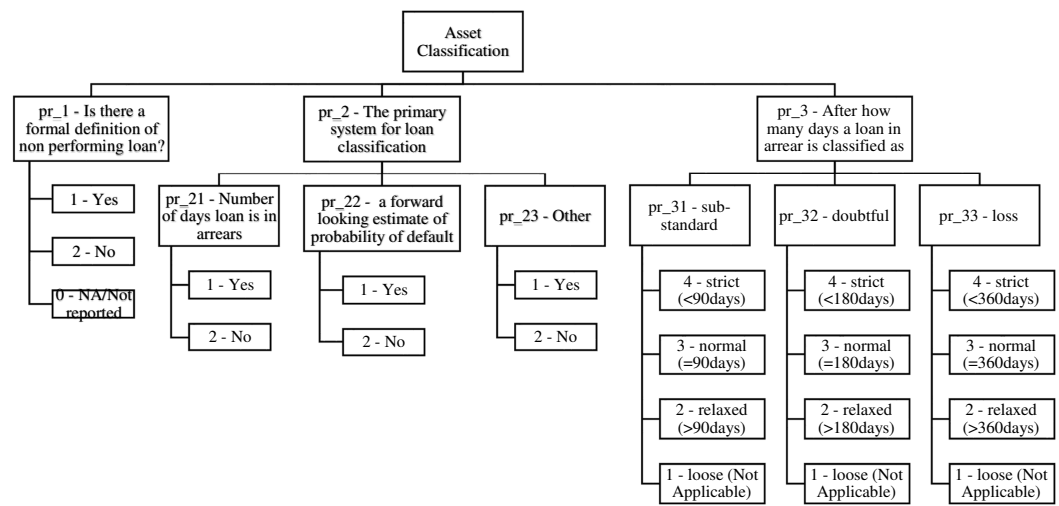


Figure B.2: **Categorical Variable used in Difference in Difference Estimation**

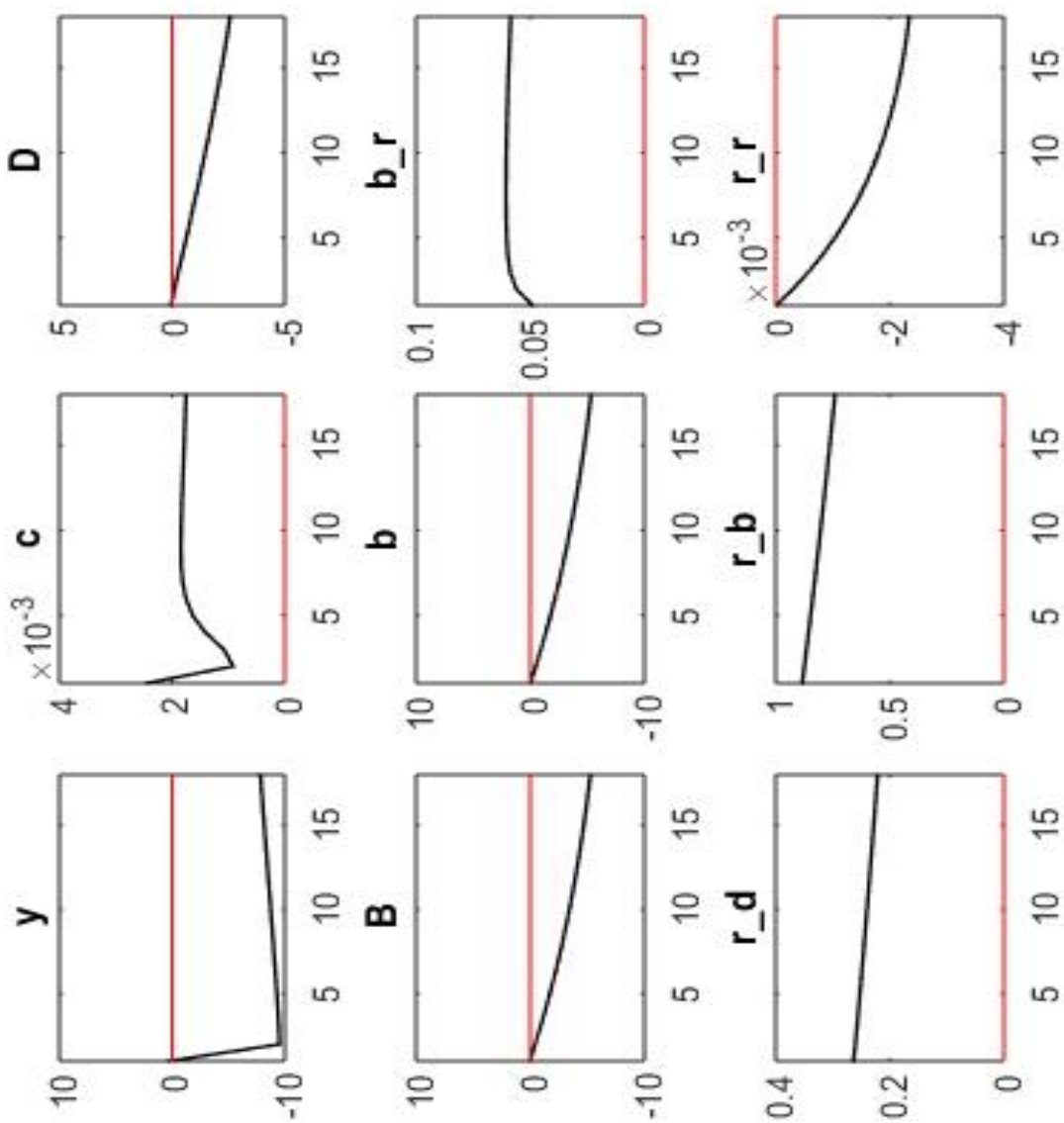


Figure B.3: Shock to Dis-utility from Deposits

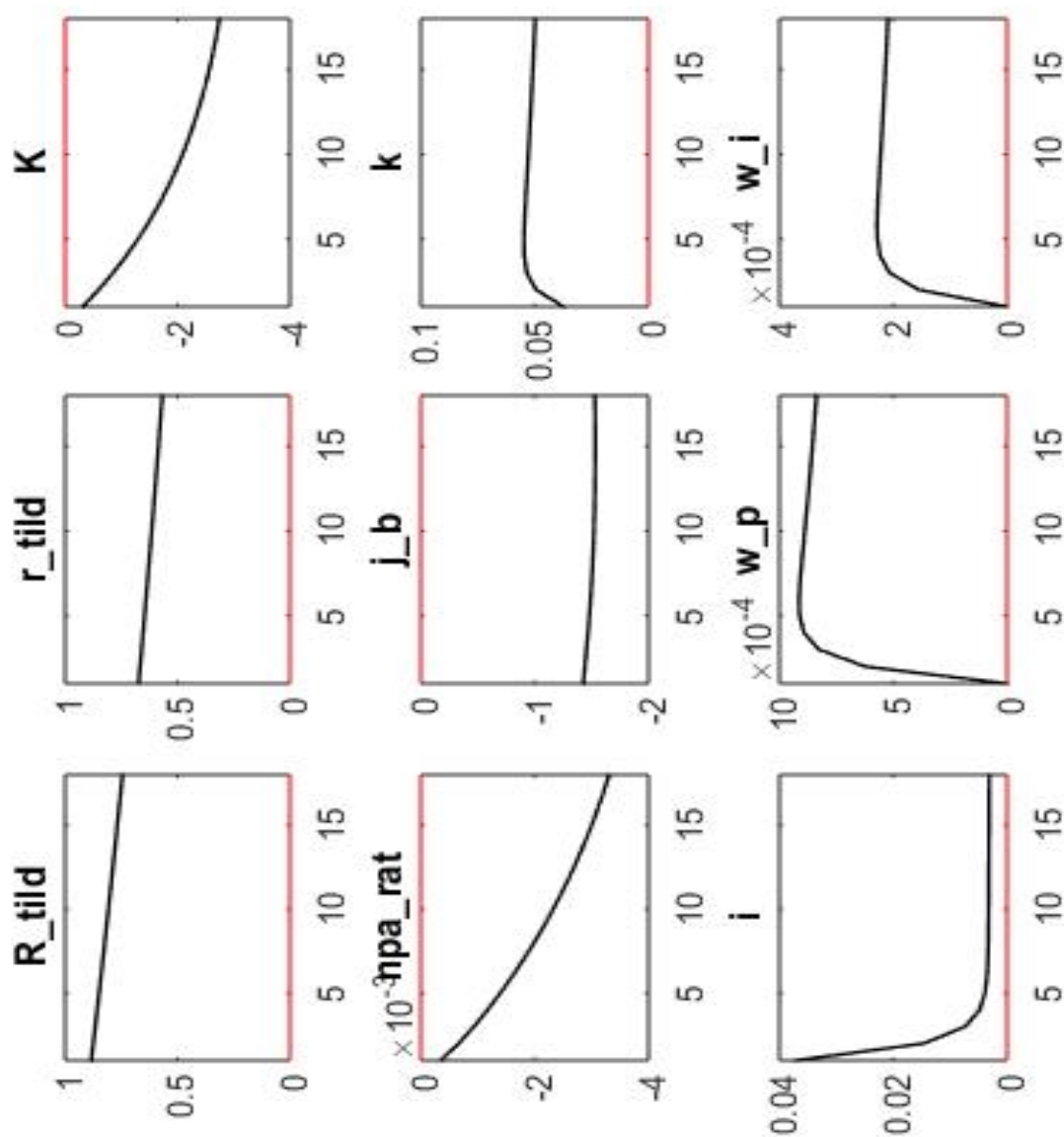


Figure B.4: Shock to Dis-utility from Deposits



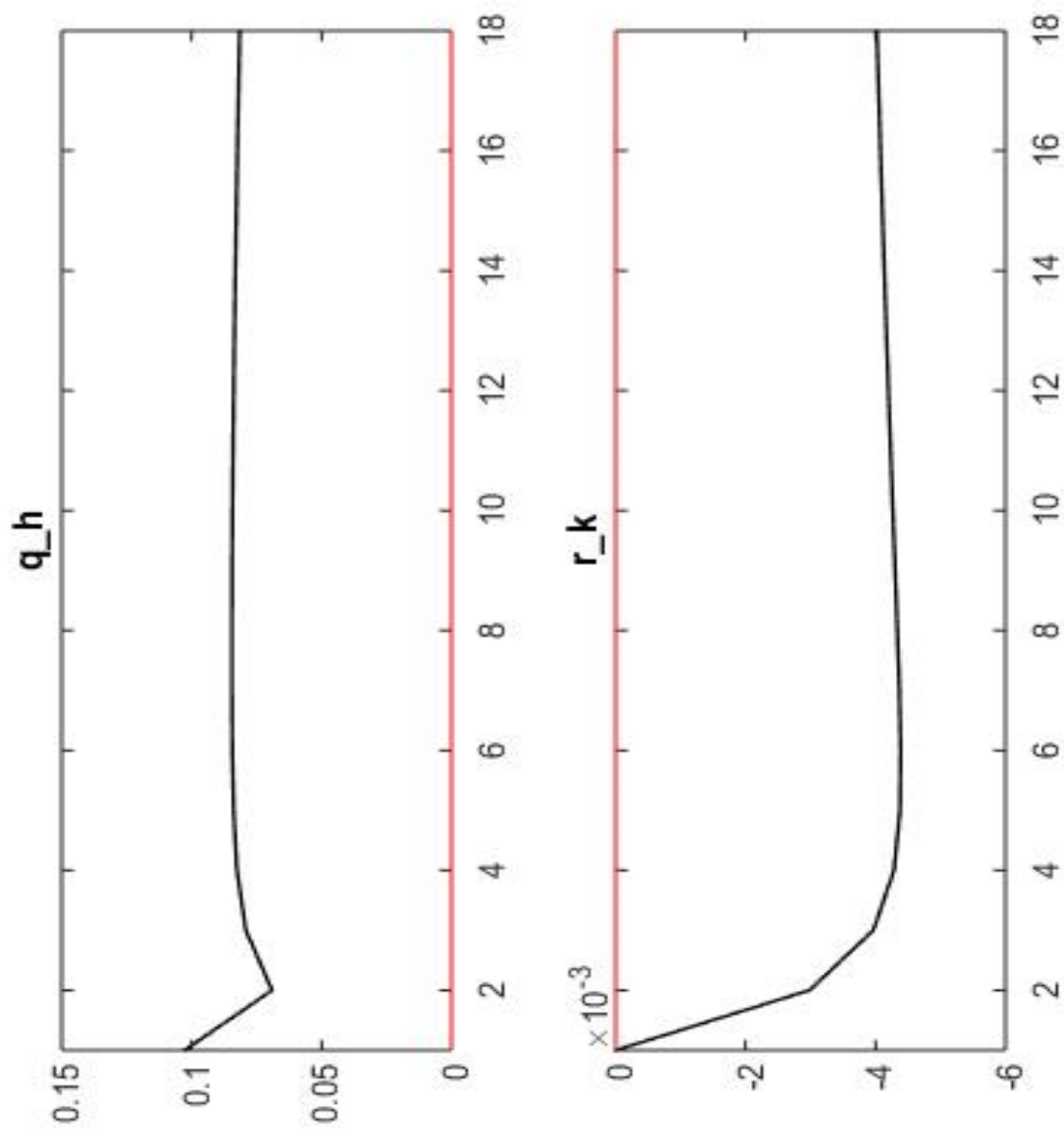


Figure B.5: Shock to Dis-utility from Deposits

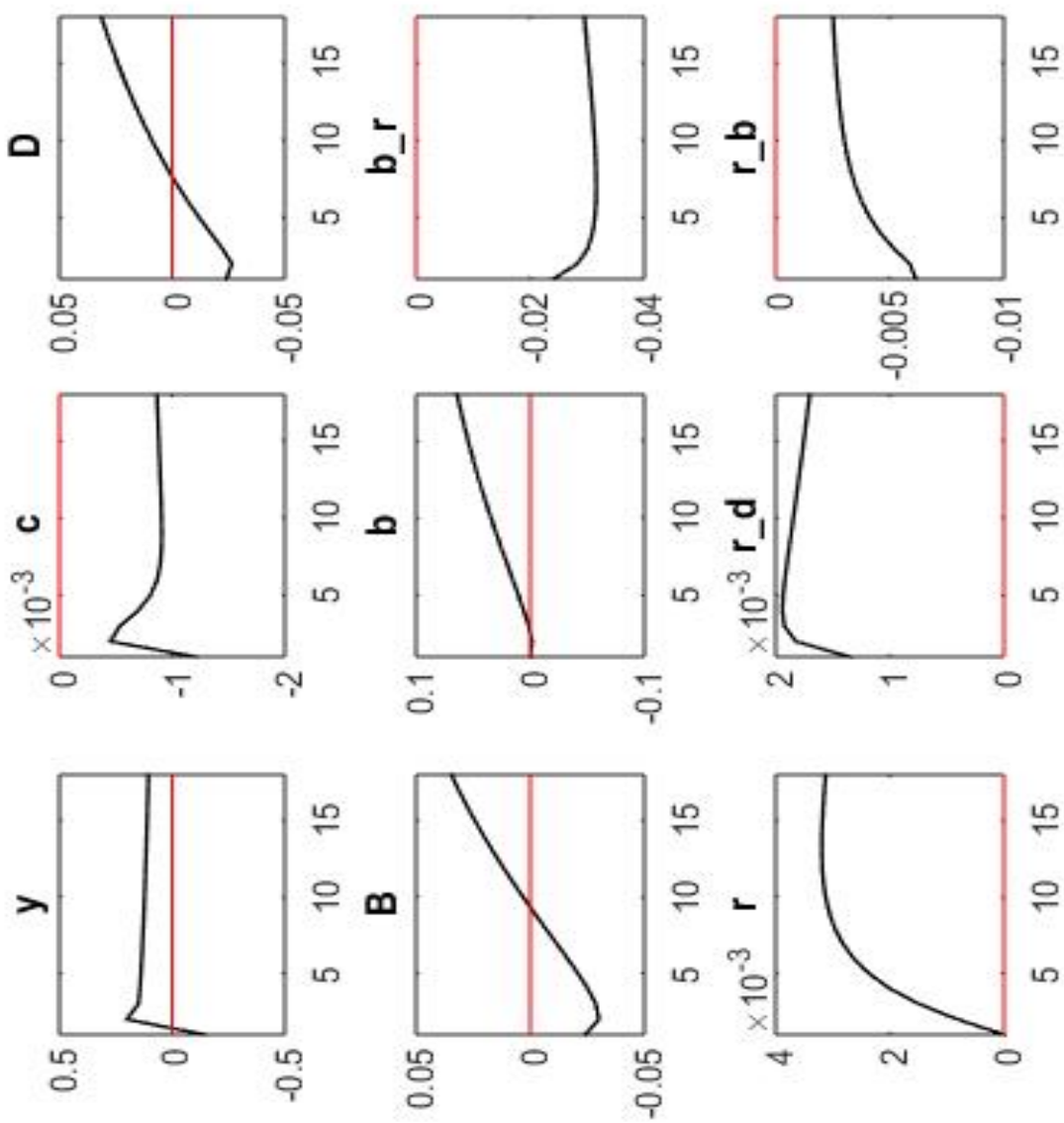


Figure B.6: Shock to Mark-up on Loan Disbursing BCAs

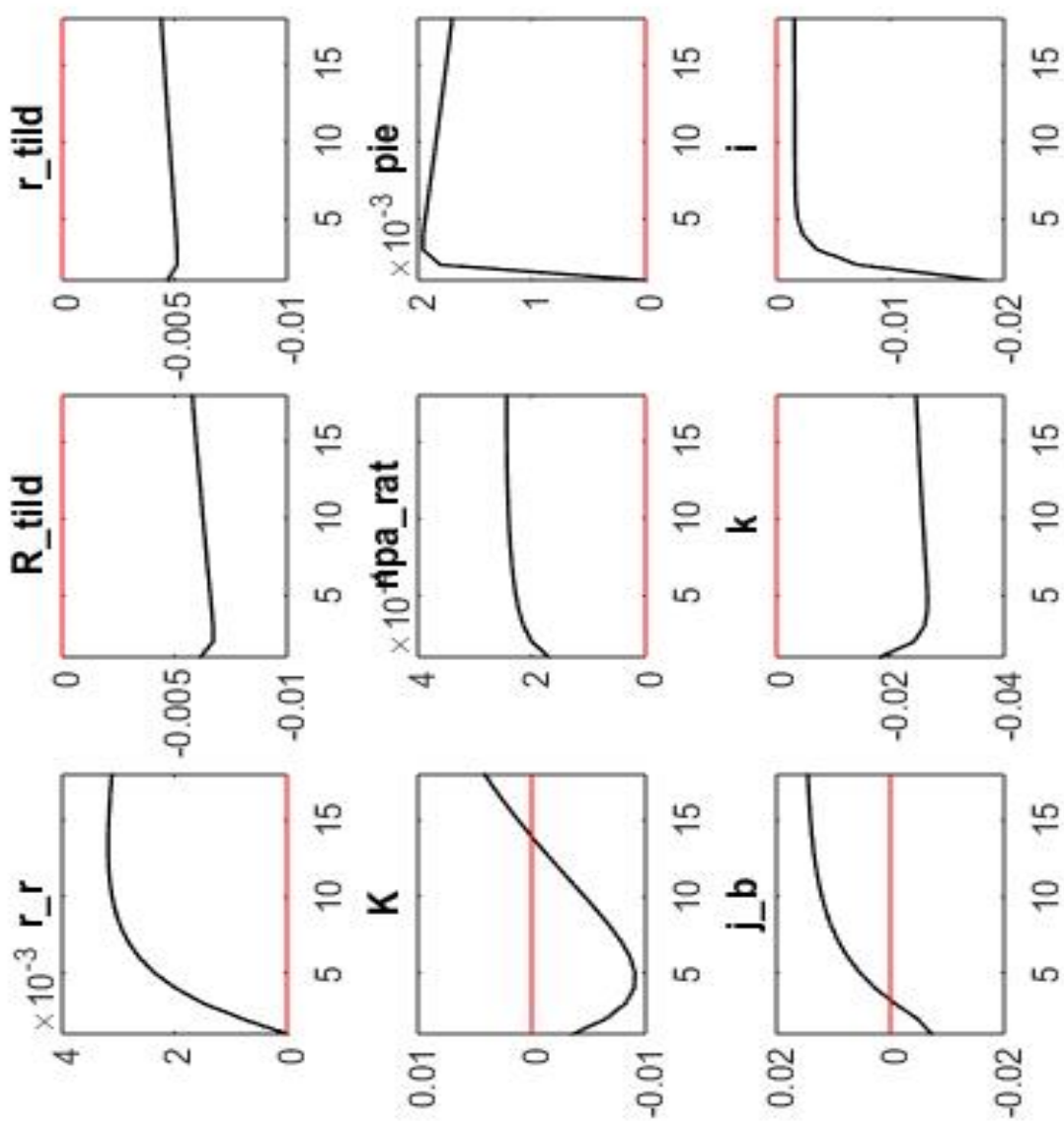


Figure B.7: Shock to Mark-up on Loan Disbursing BCAs

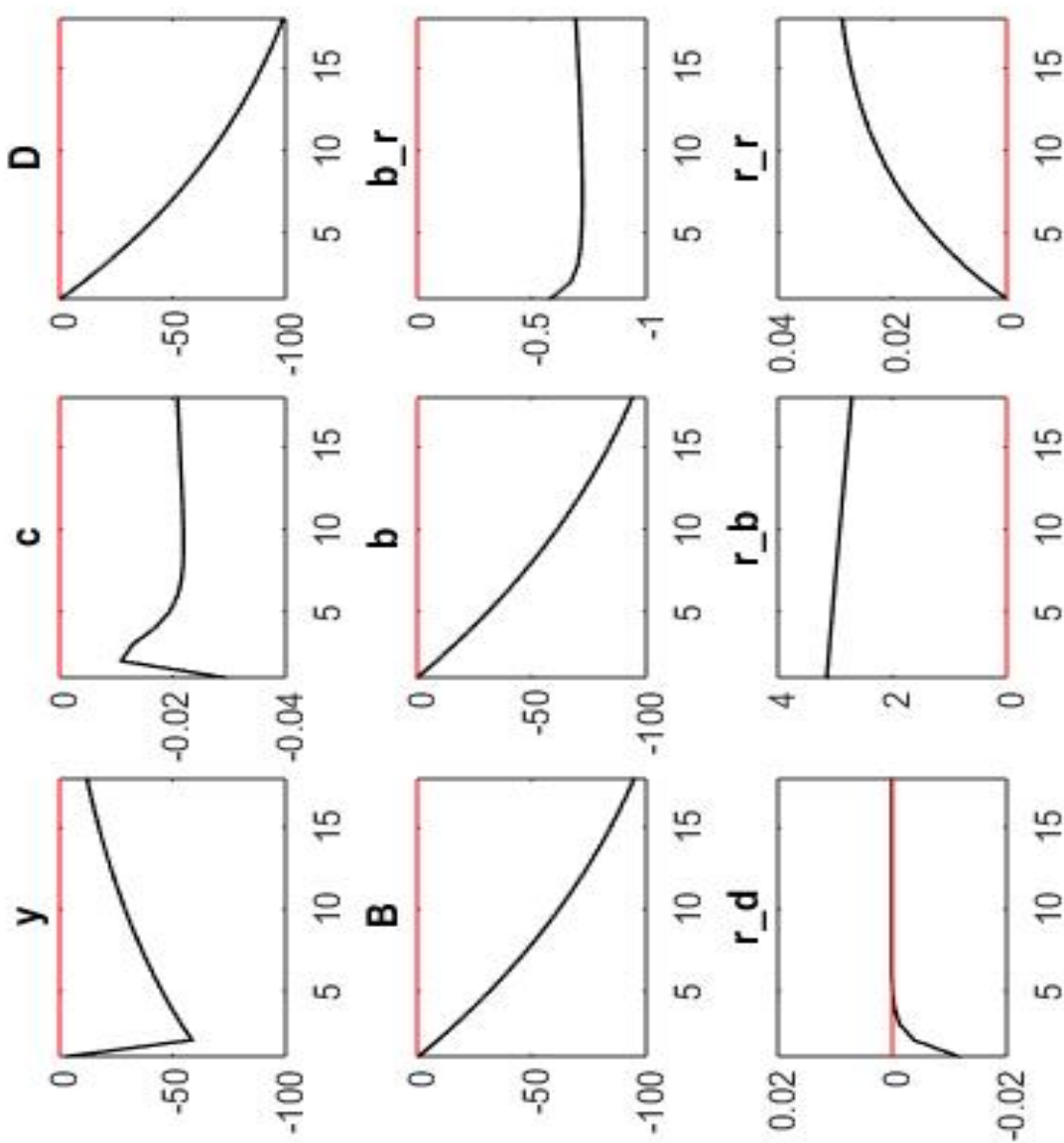


Figure B.8: Shock to Repayment Rates

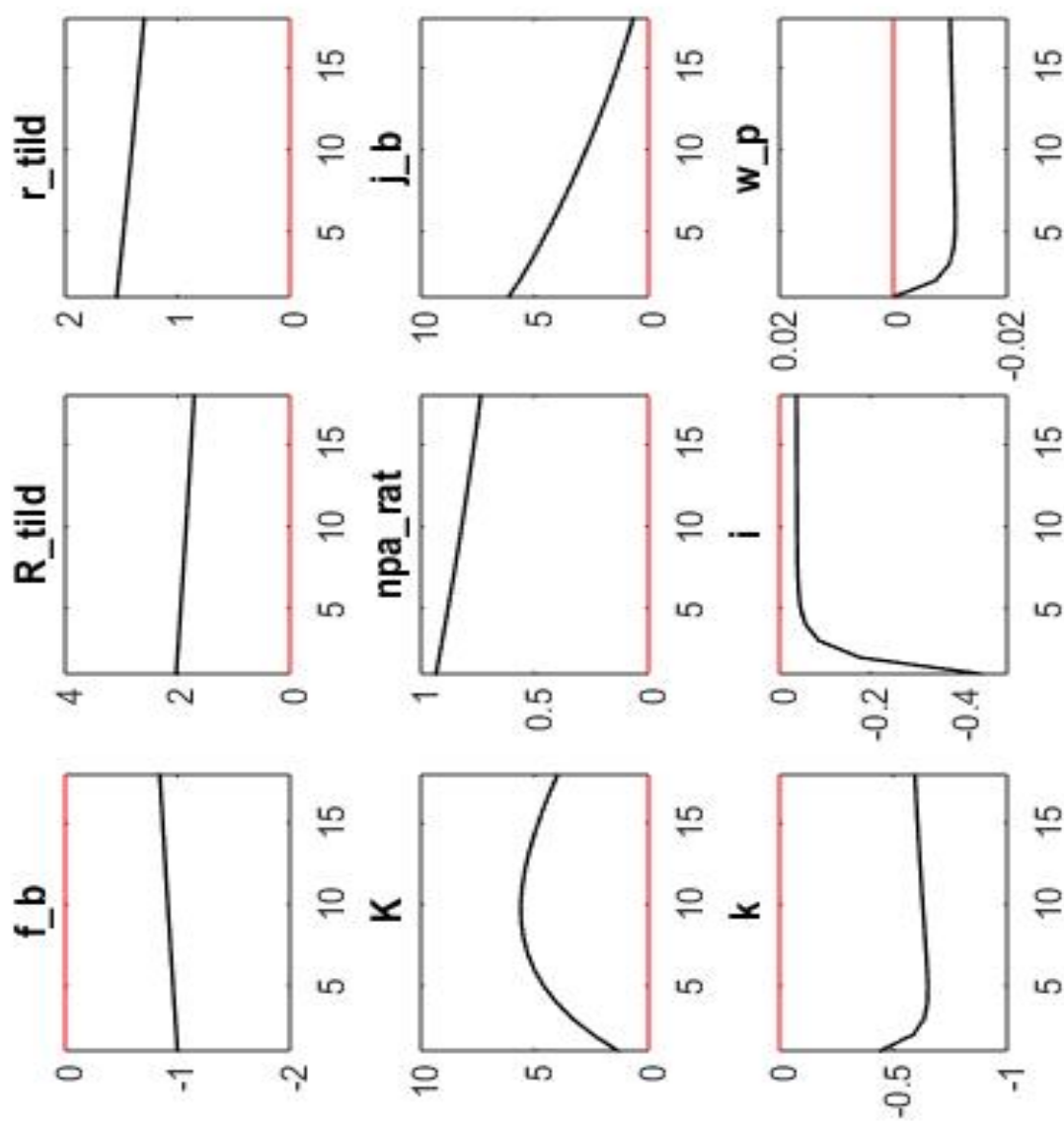


Figure B.9: Shock to Repayment Rates

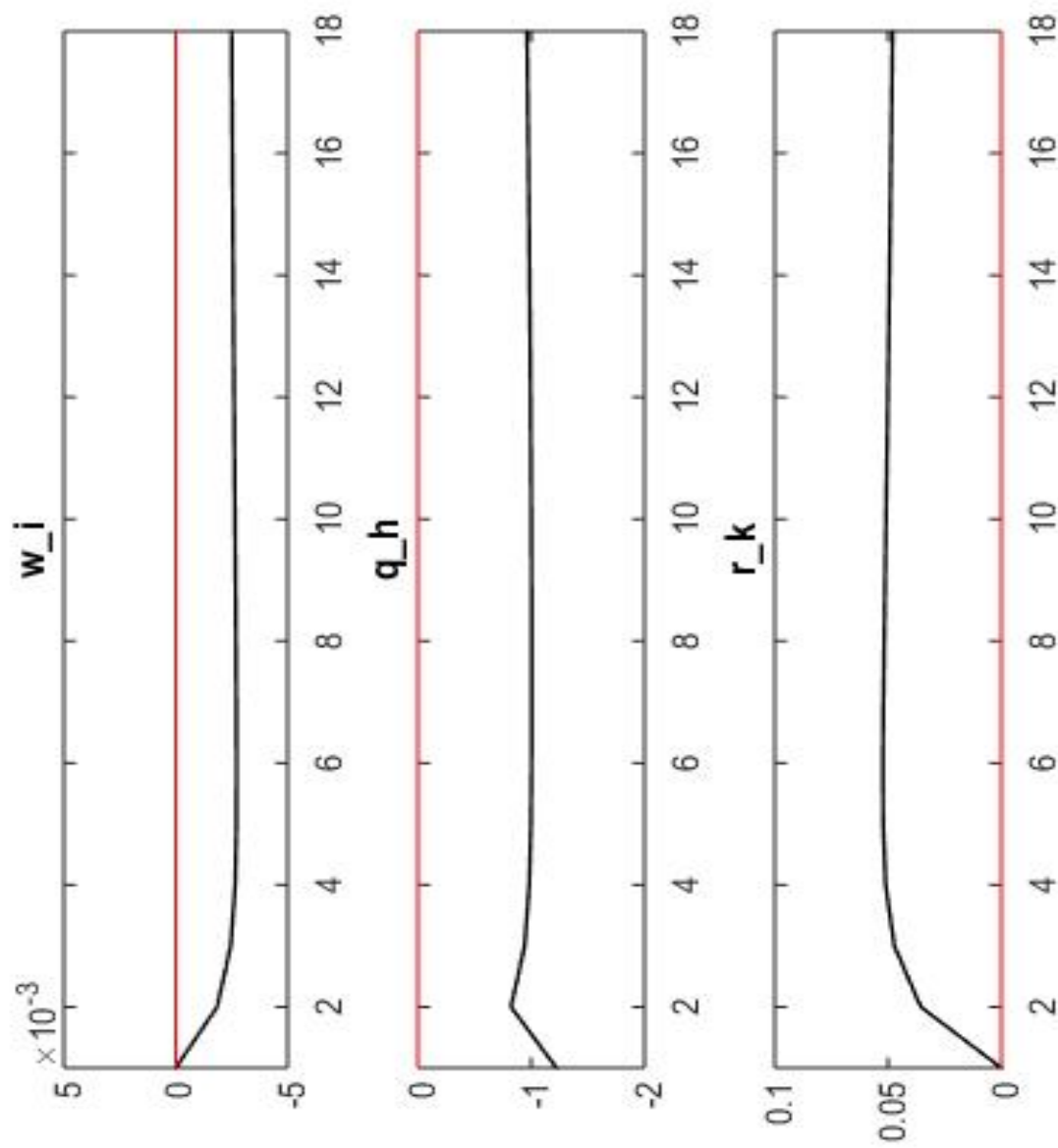


Figure B.10: Shock to Repayment Rates

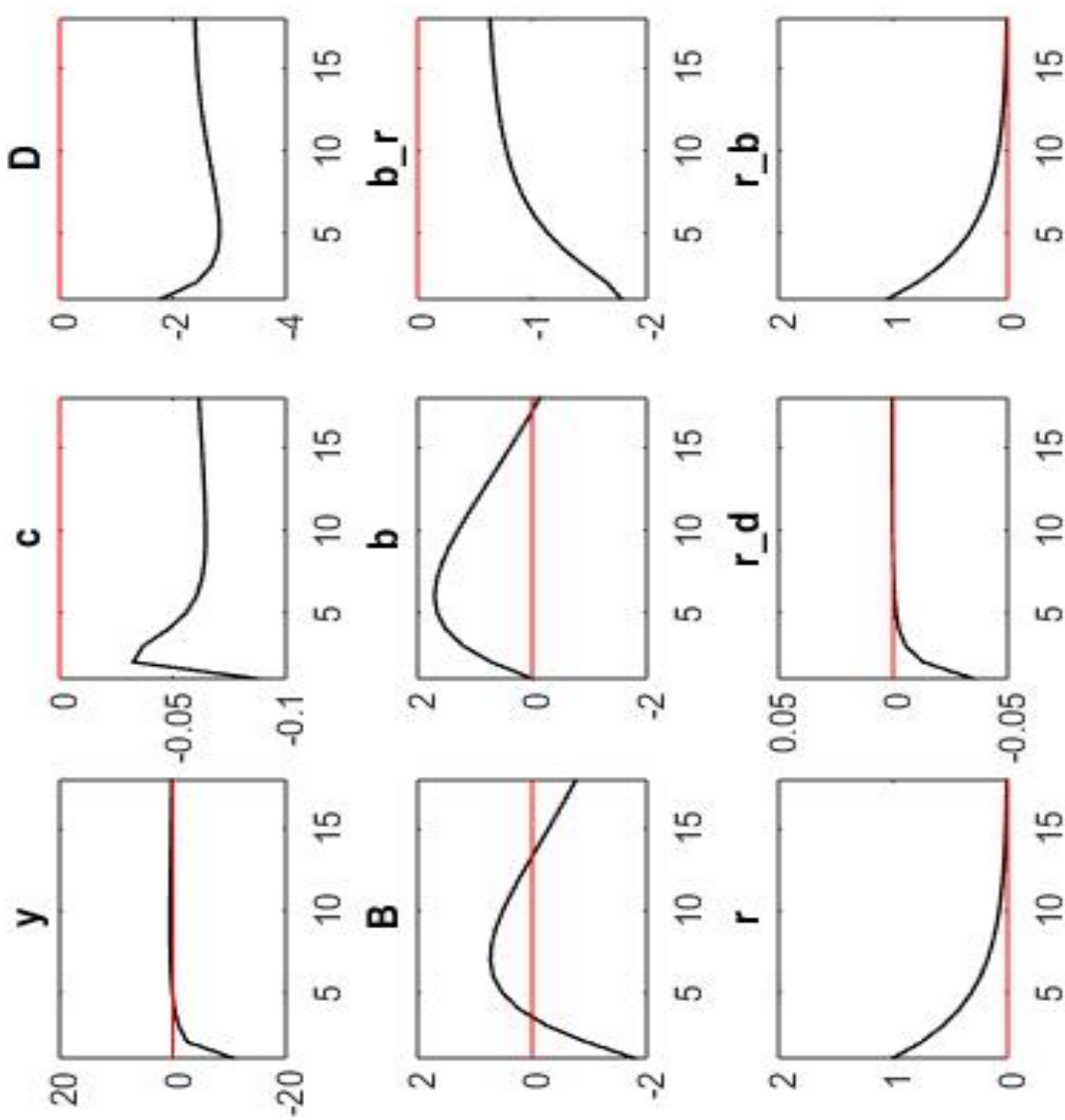


Figure B.11: Transmission of a Contractionary Monetary Policy

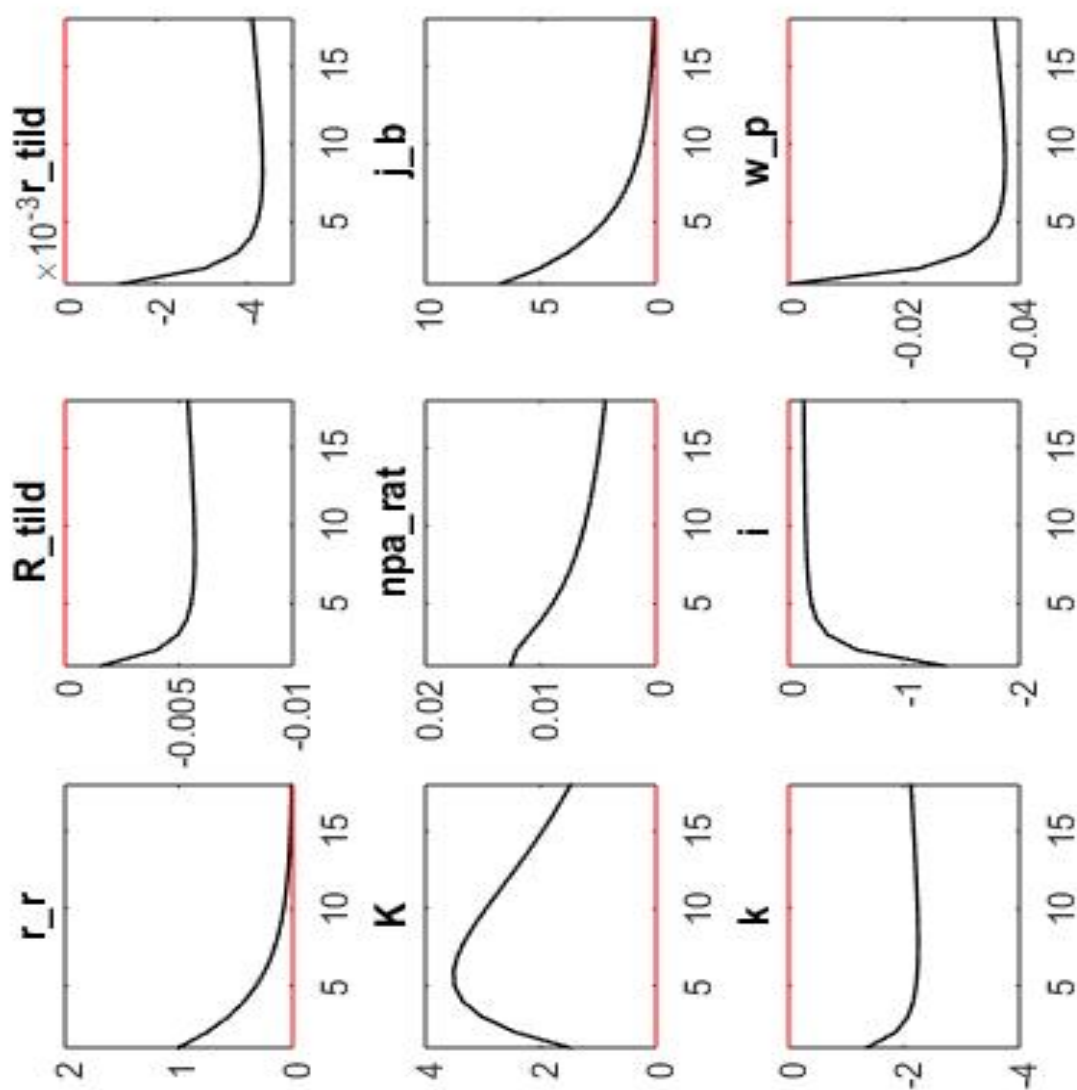


Figure B.12: Transmission of a Contractionary Monetary Policy



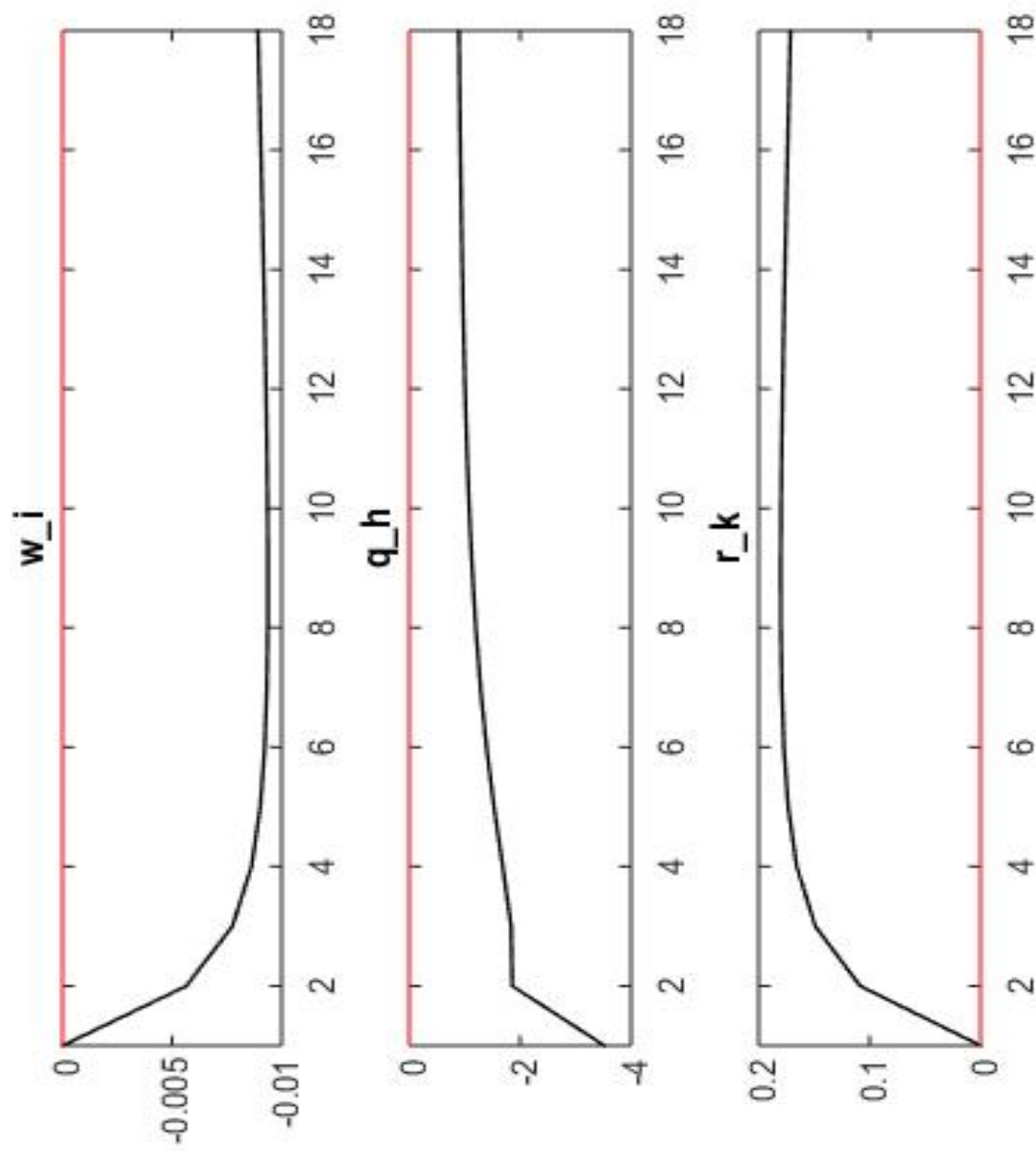


Figure B.13: Transmission of a Contractionary Monetary Policy

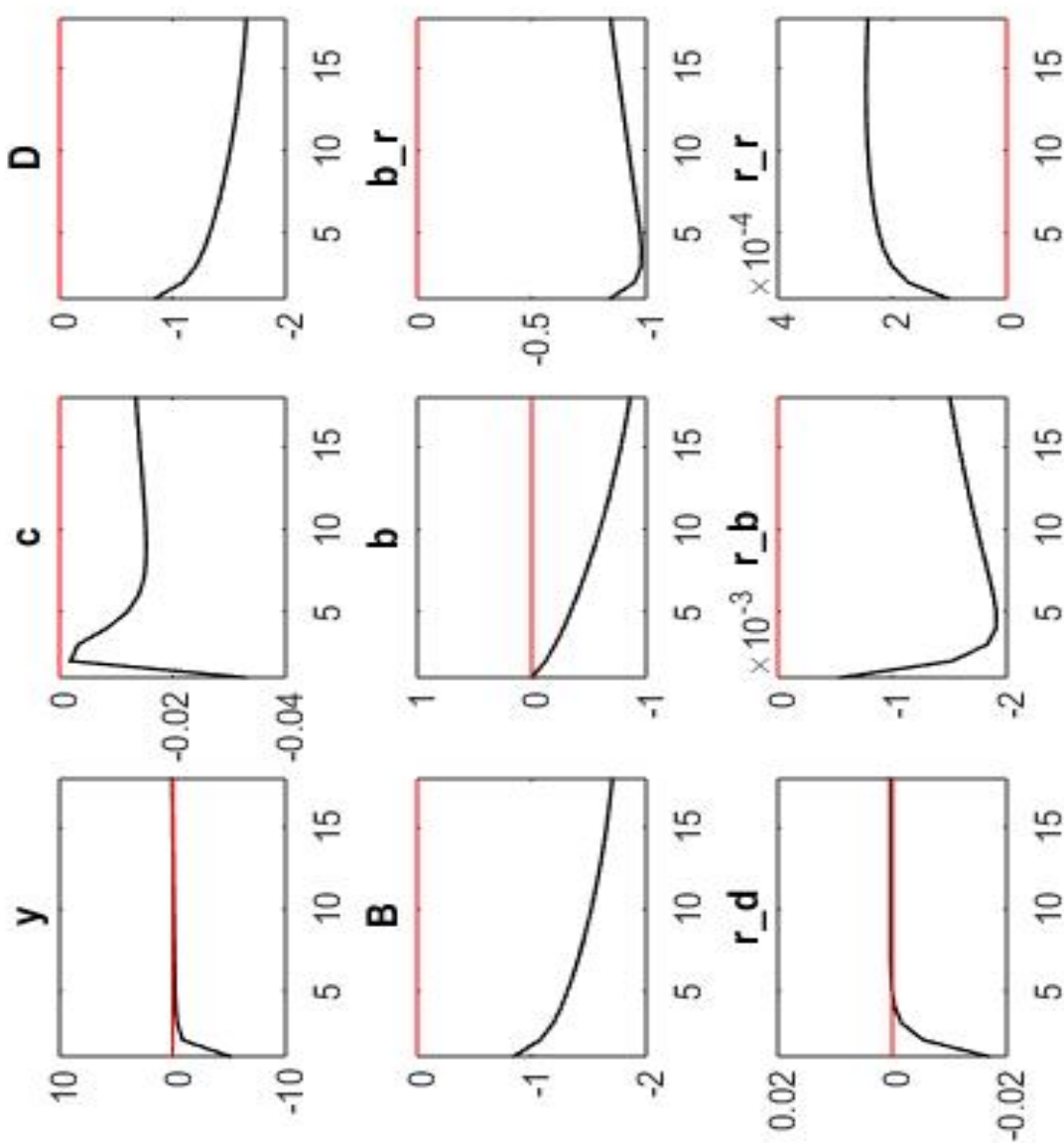


Figure B.14: Transmission of a Contractionary Macro-Prudential Policy

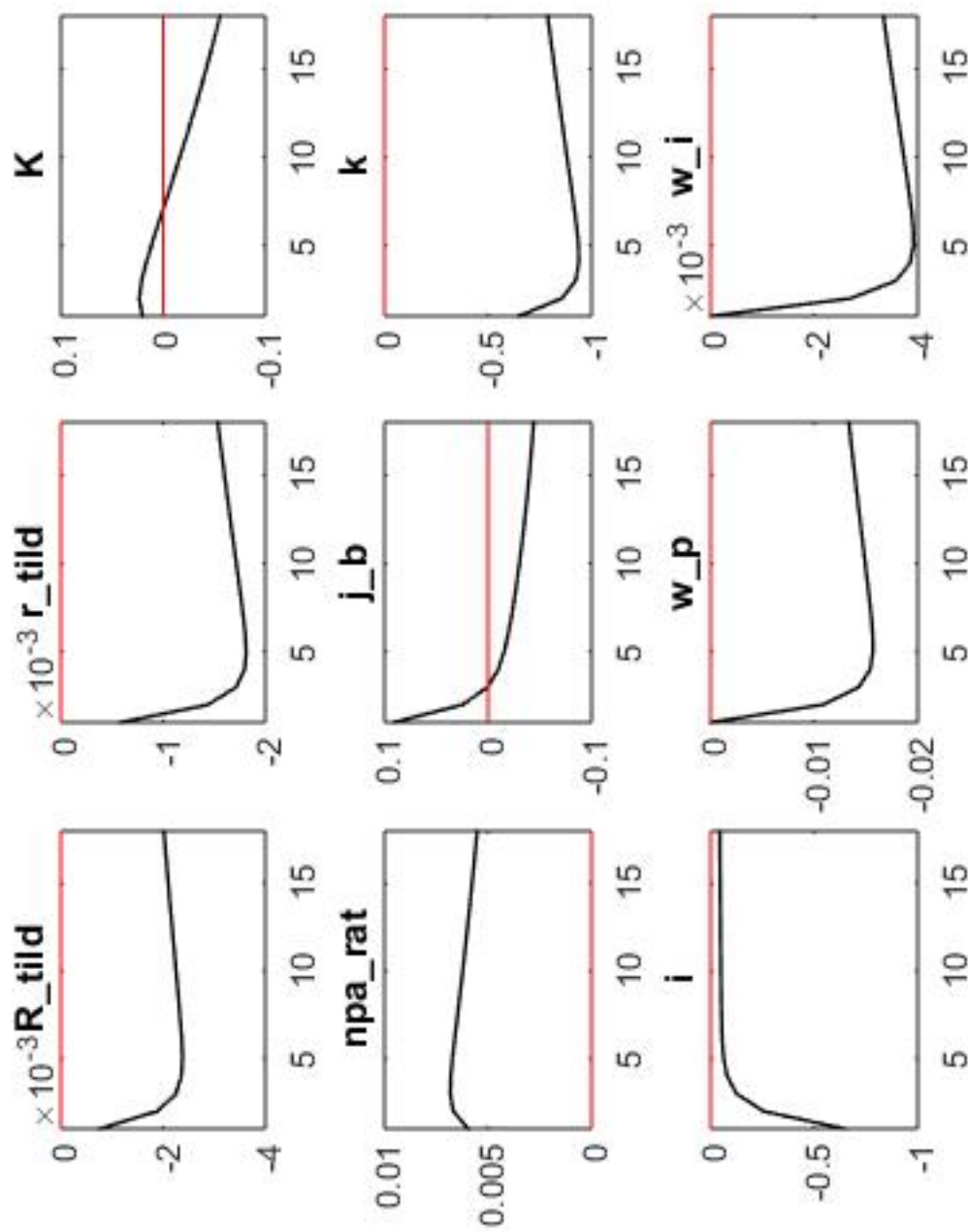


Figure B.15: Transmission of a Contractionary Macro-Prudential Policy-1

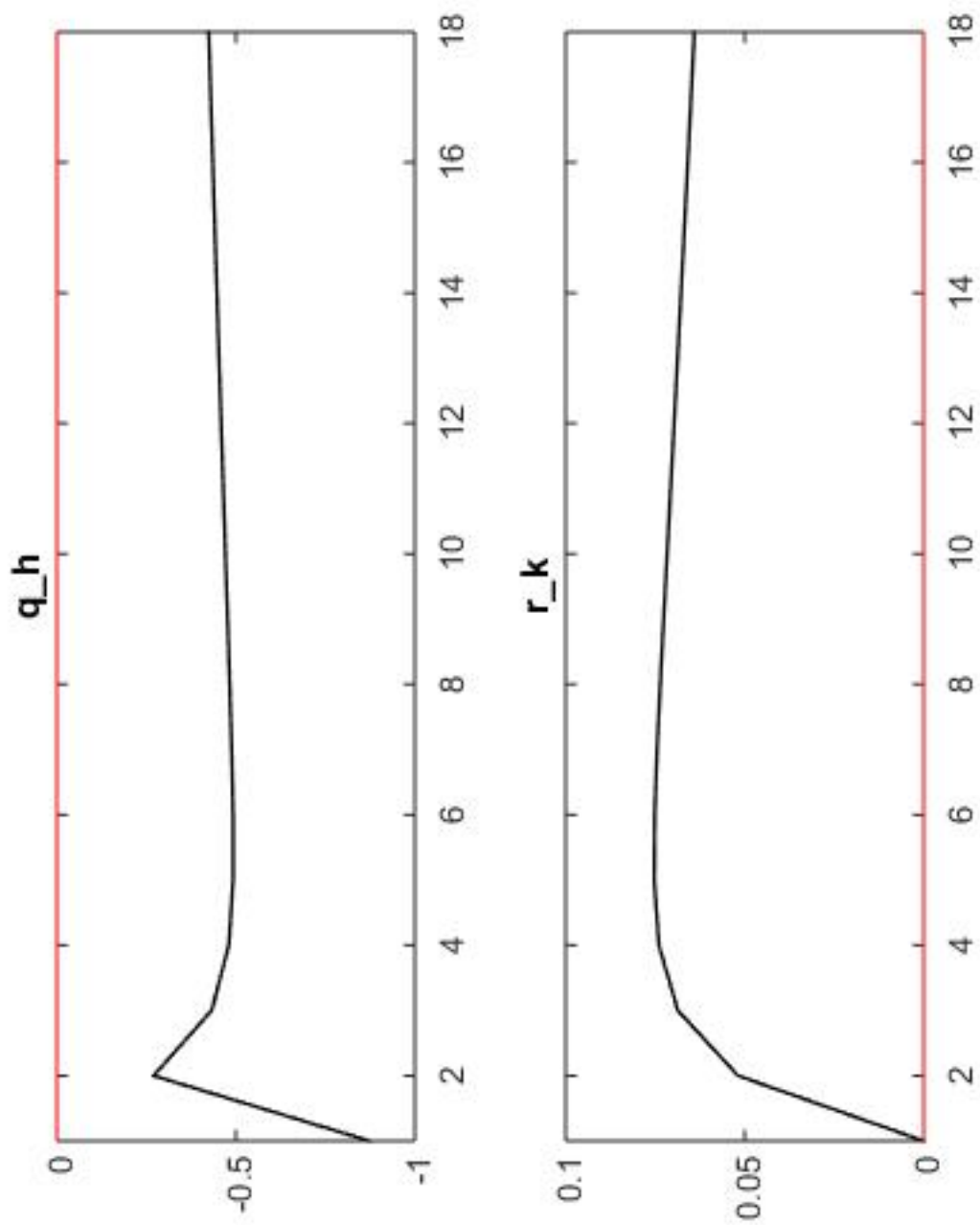


Figure B.16: Transmission of a Contractionary Macro-Prudential Policy-2

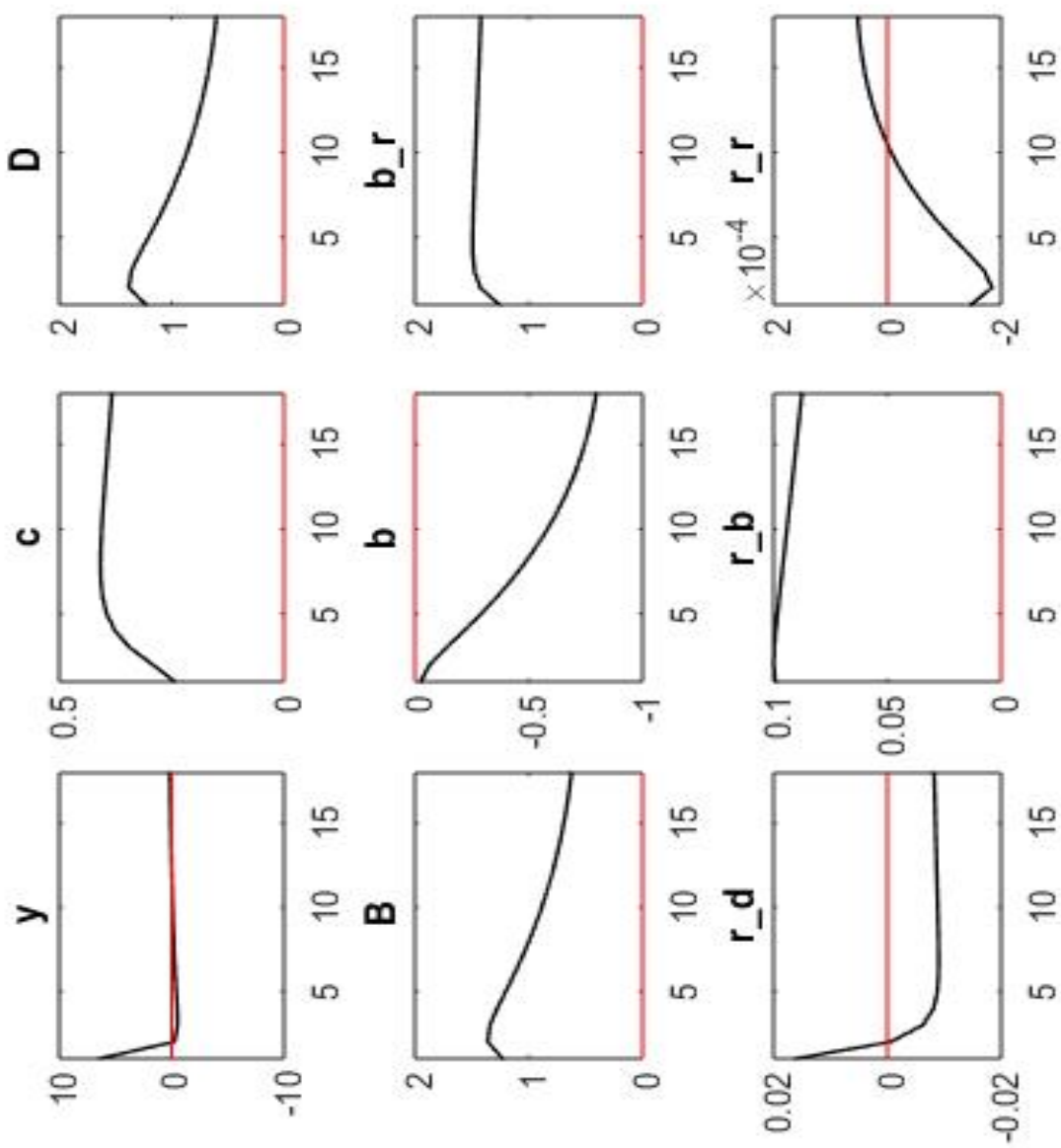


Figure B.17: Transmission of a Positive Technology Shock

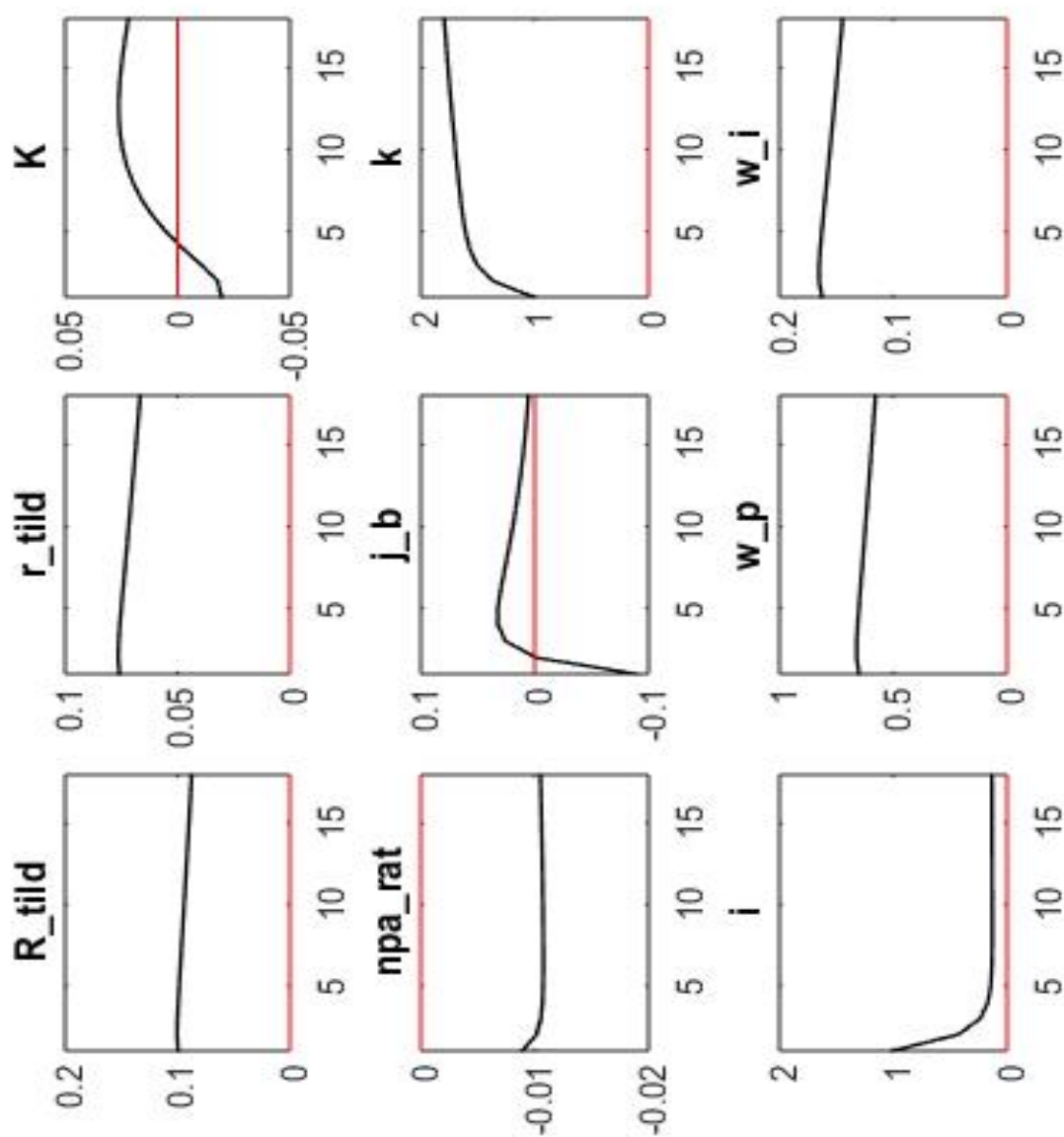


Figure B.18: Transmission of a Positive Technology Policy

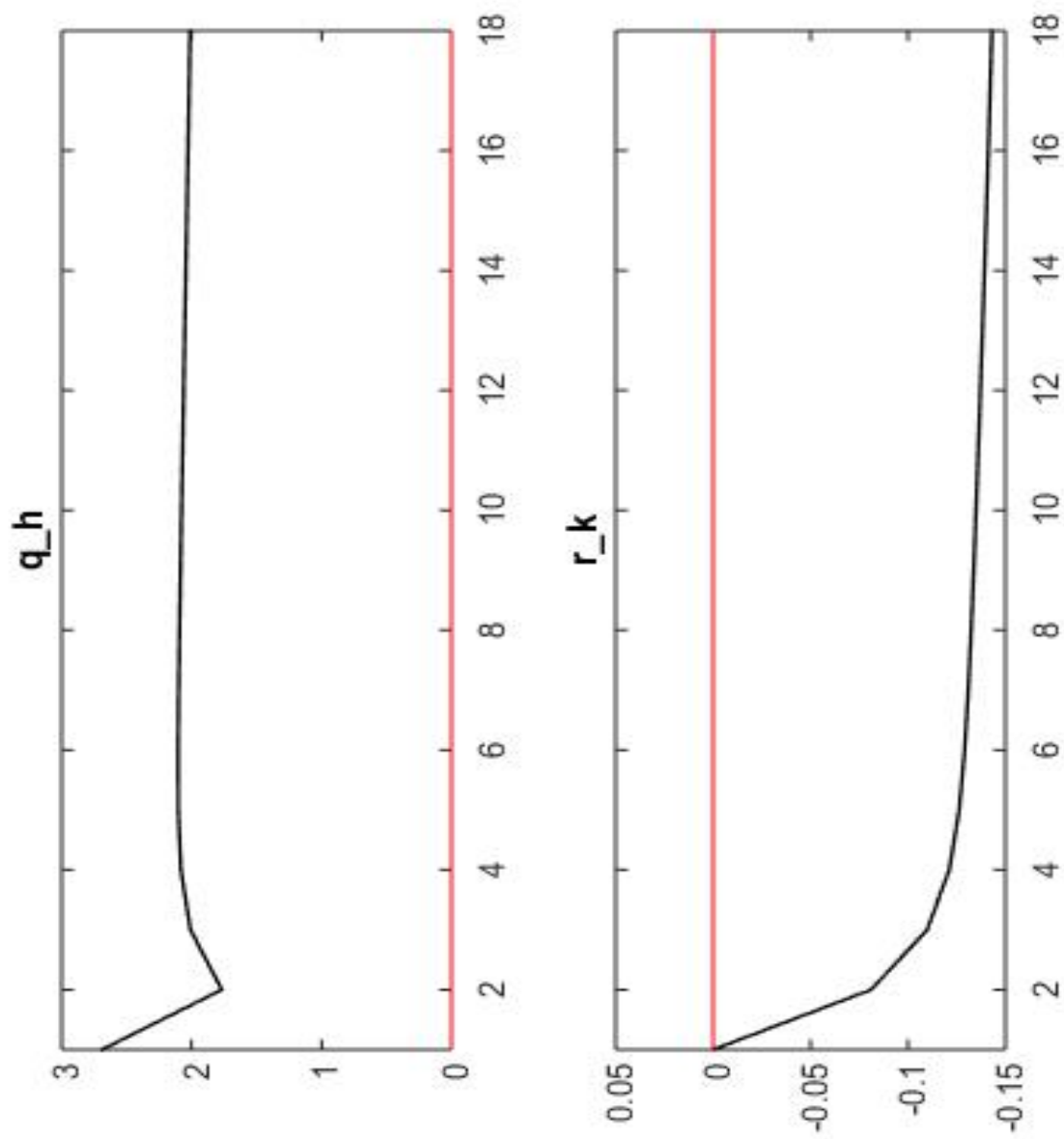


Figure B.19: Transmission of a Positive Technology Policy

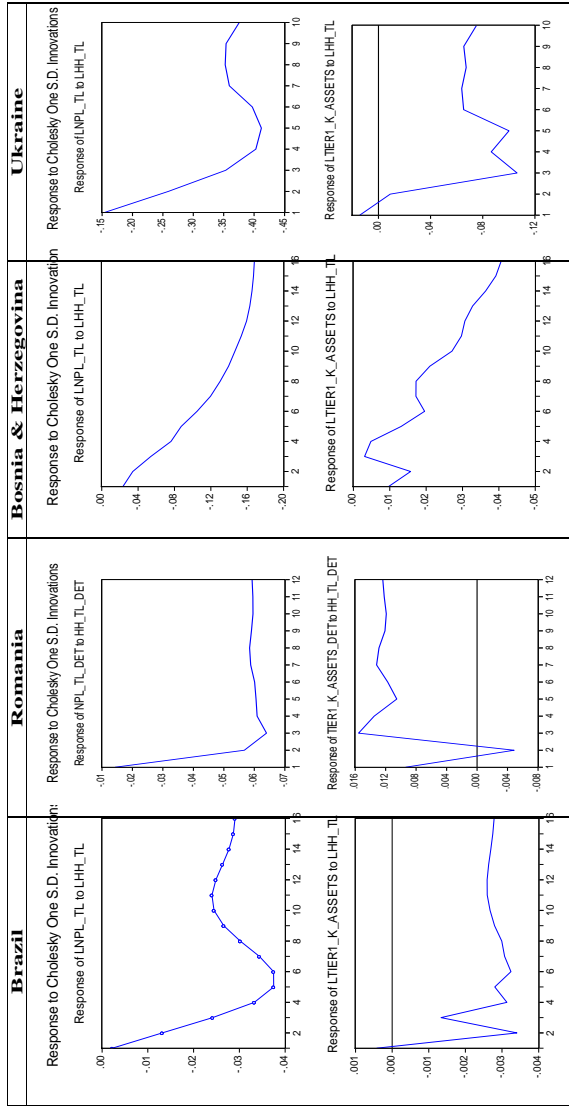


Figure B.20: Panel - IA



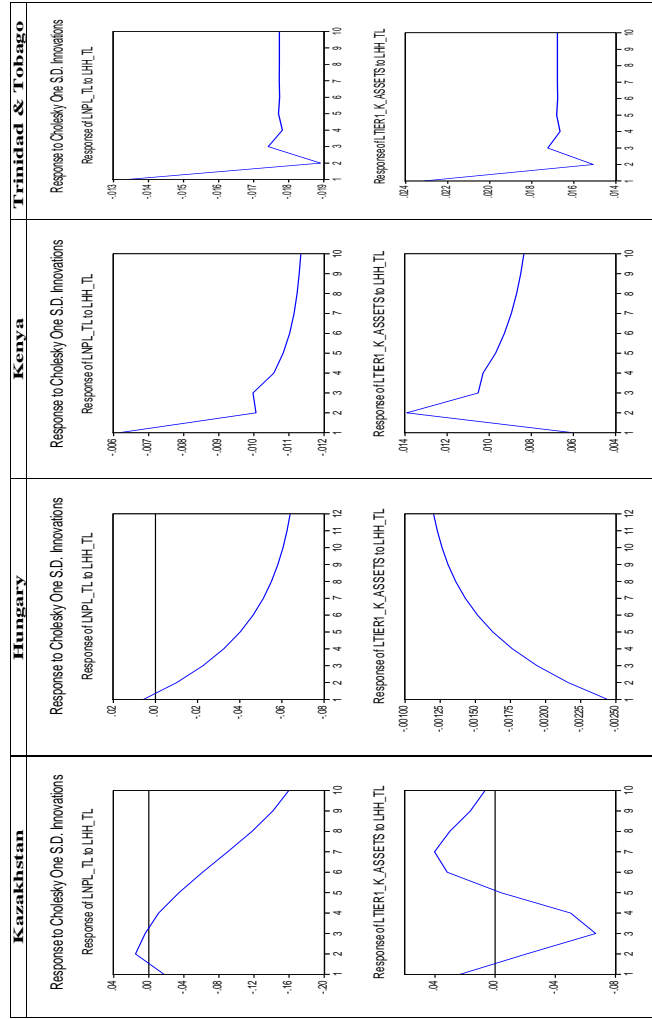


Figure B.21: Panel - IB

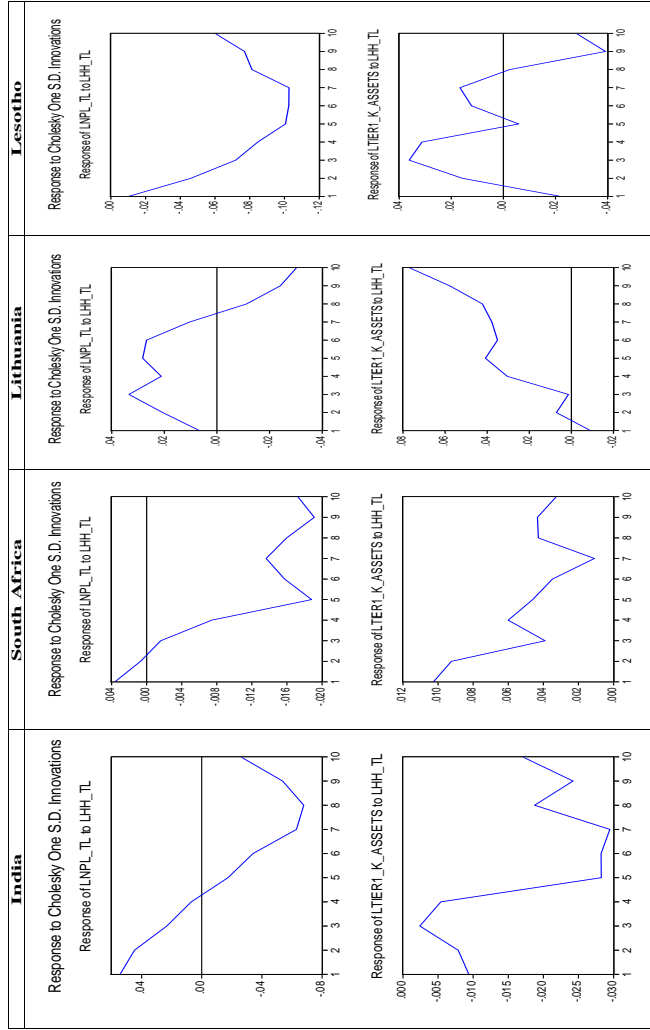


Figure B.22: Panel - B

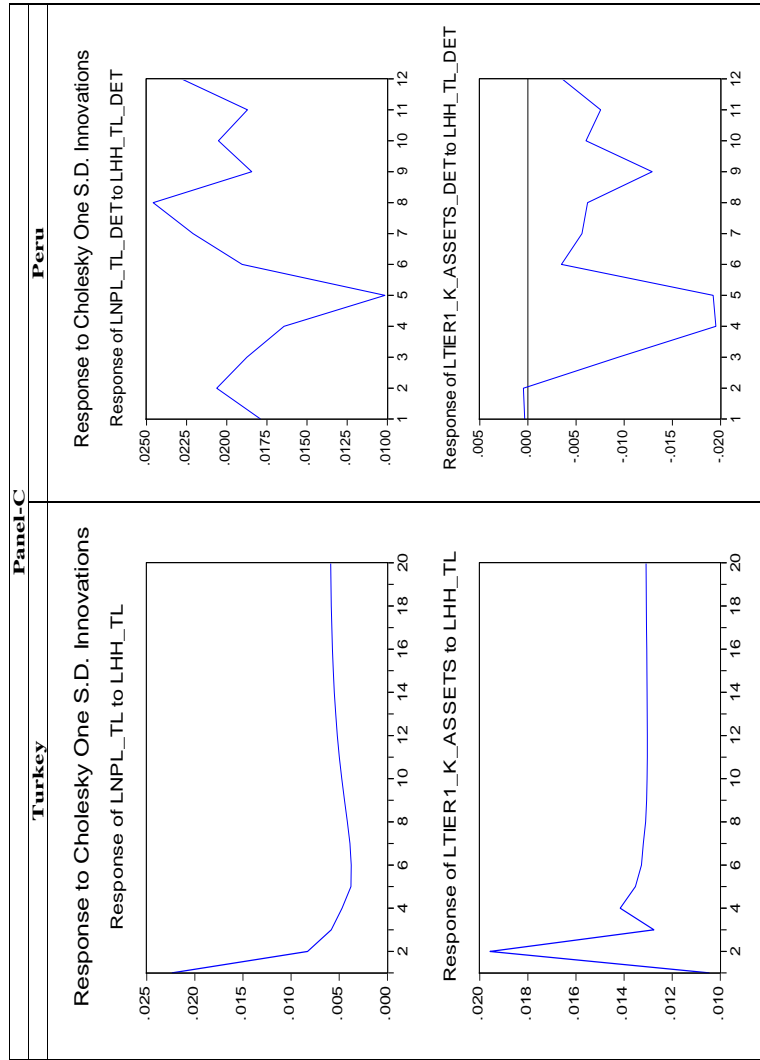


Figure B.23: Panel - C

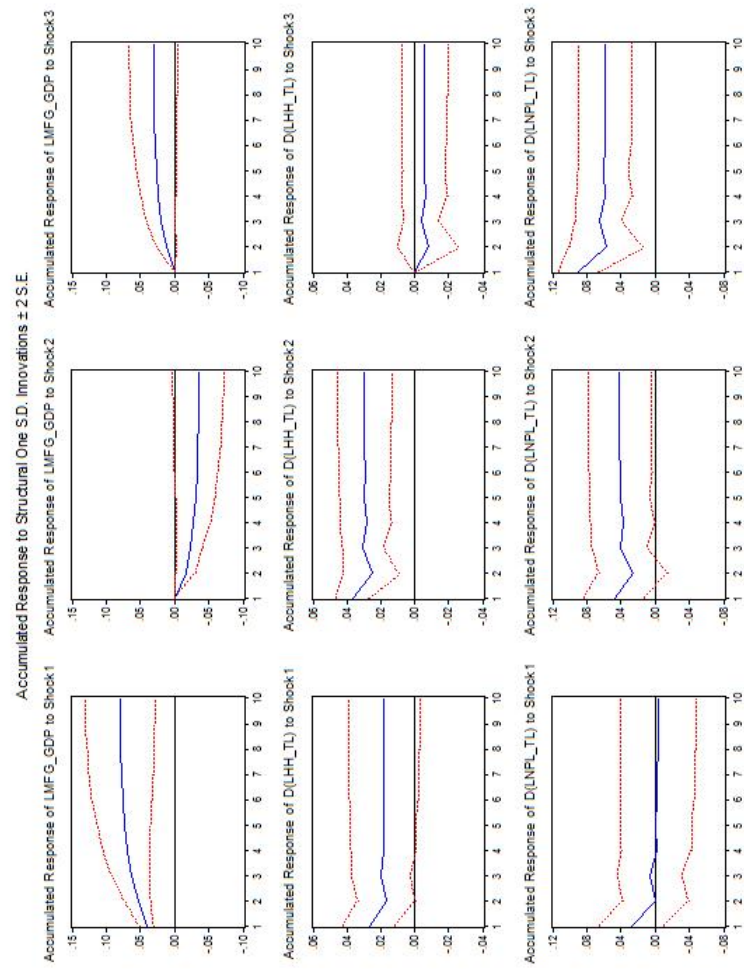


Figure B.24: Philippines

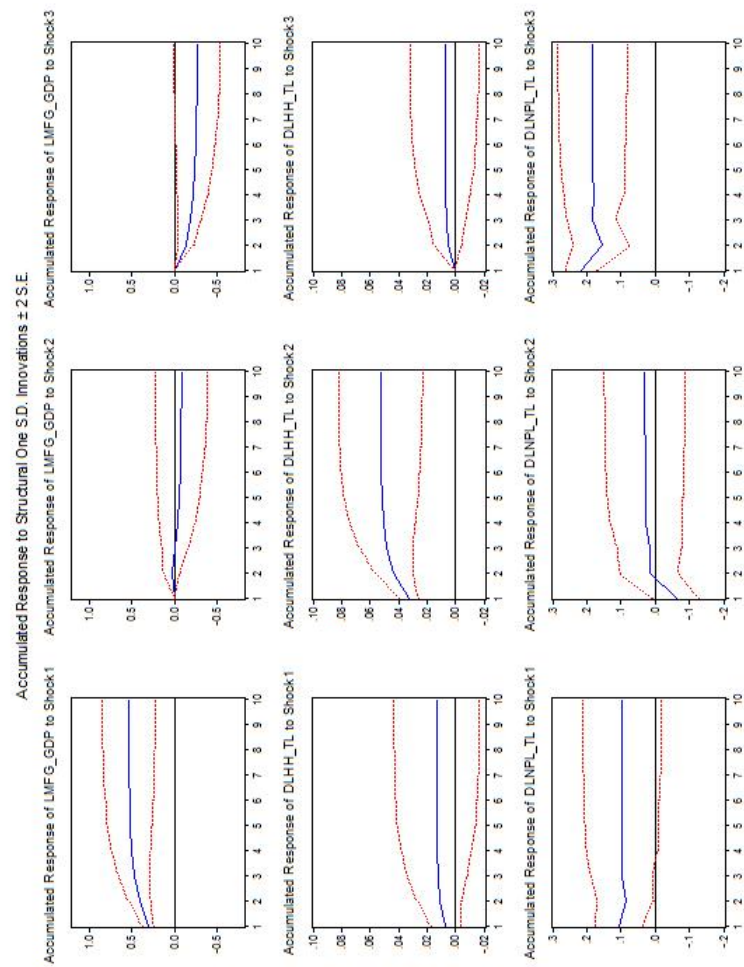


Figure B.25: Armenia

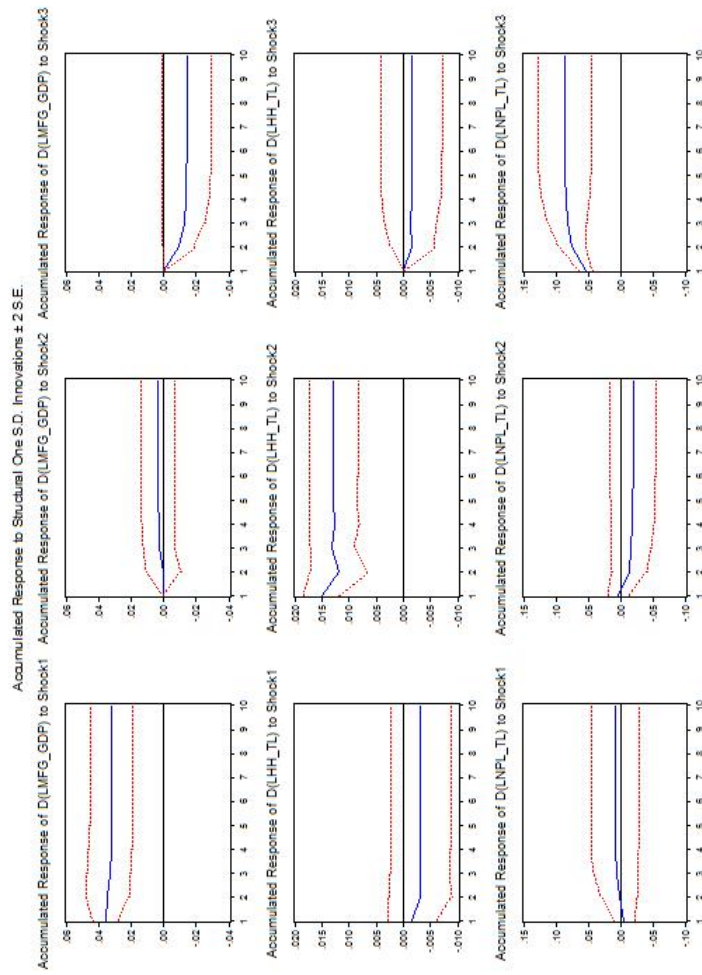


Figure B.26: Malta

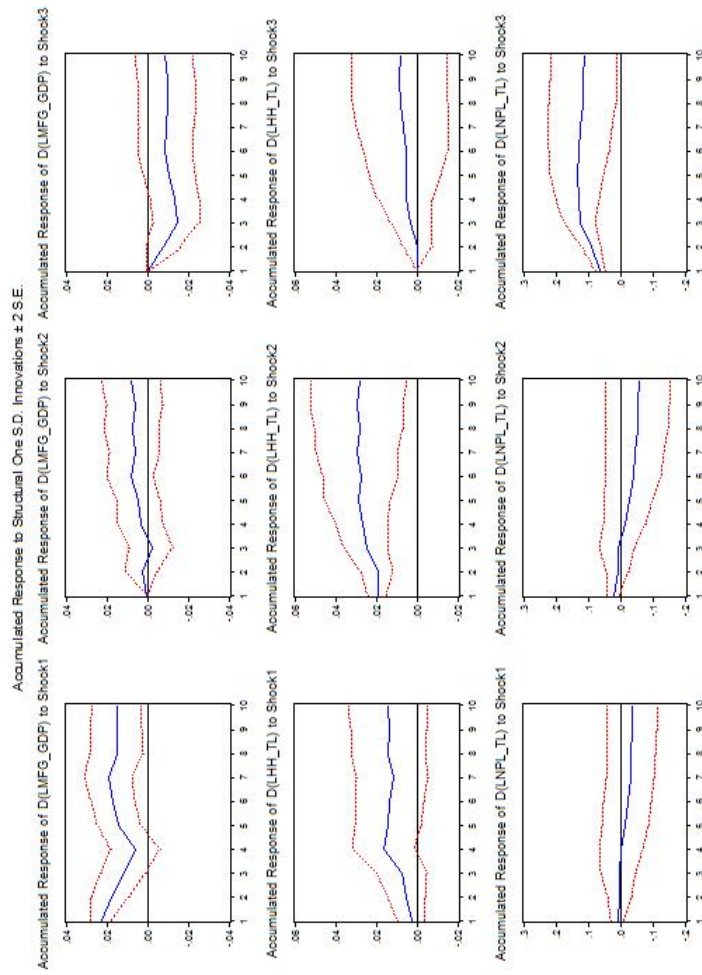


Figure B.27: Turkey

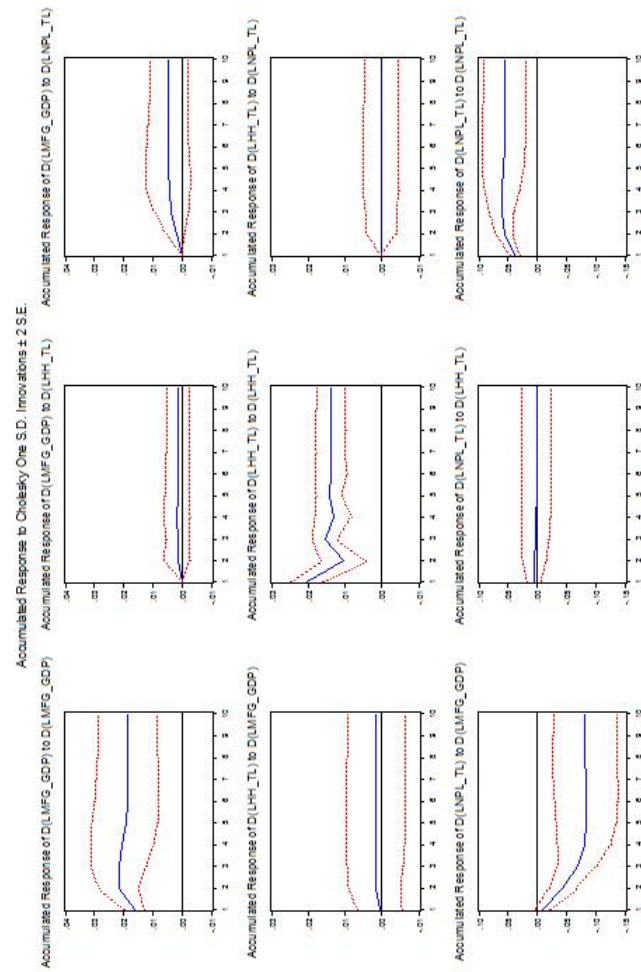


Figure B.28: Brazil



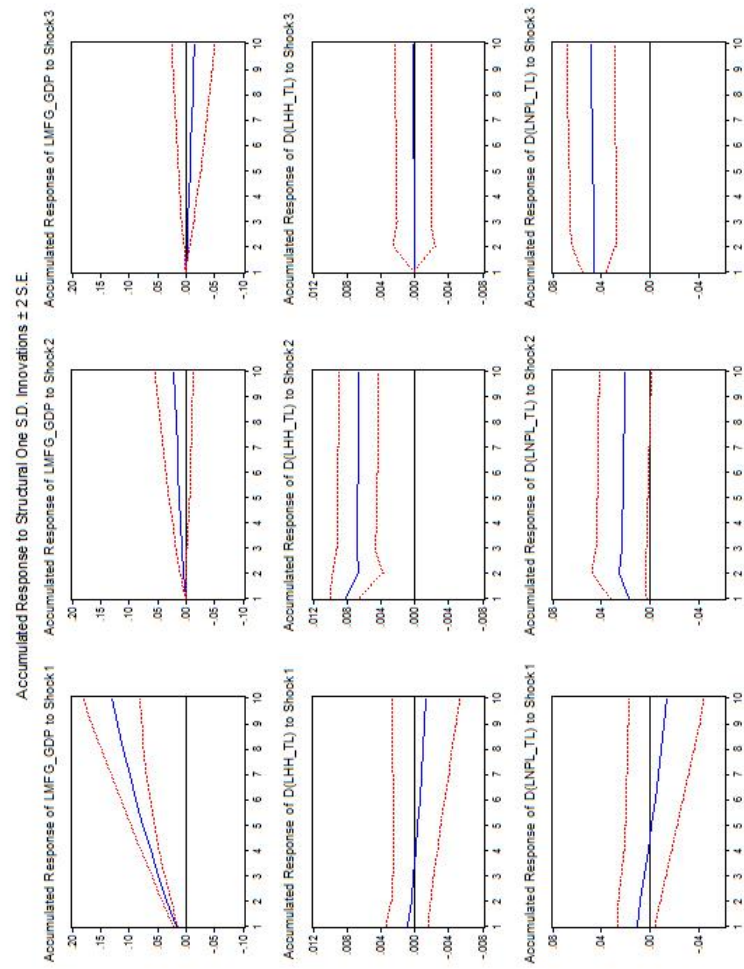


Figure B.29: Malaysia

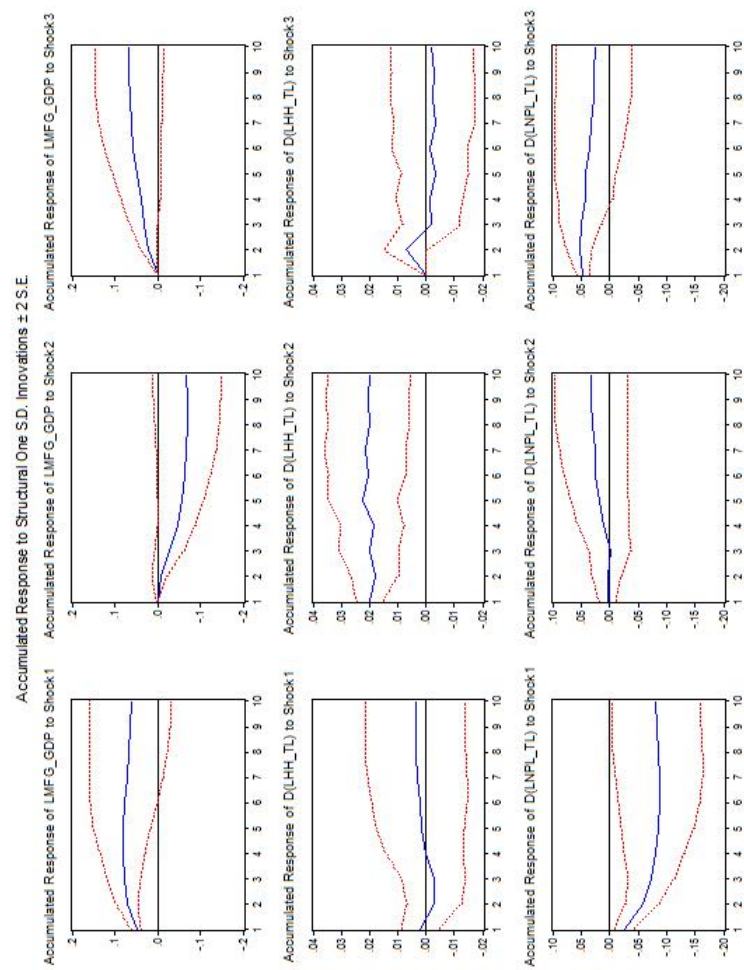


Figure B.30: Thailand

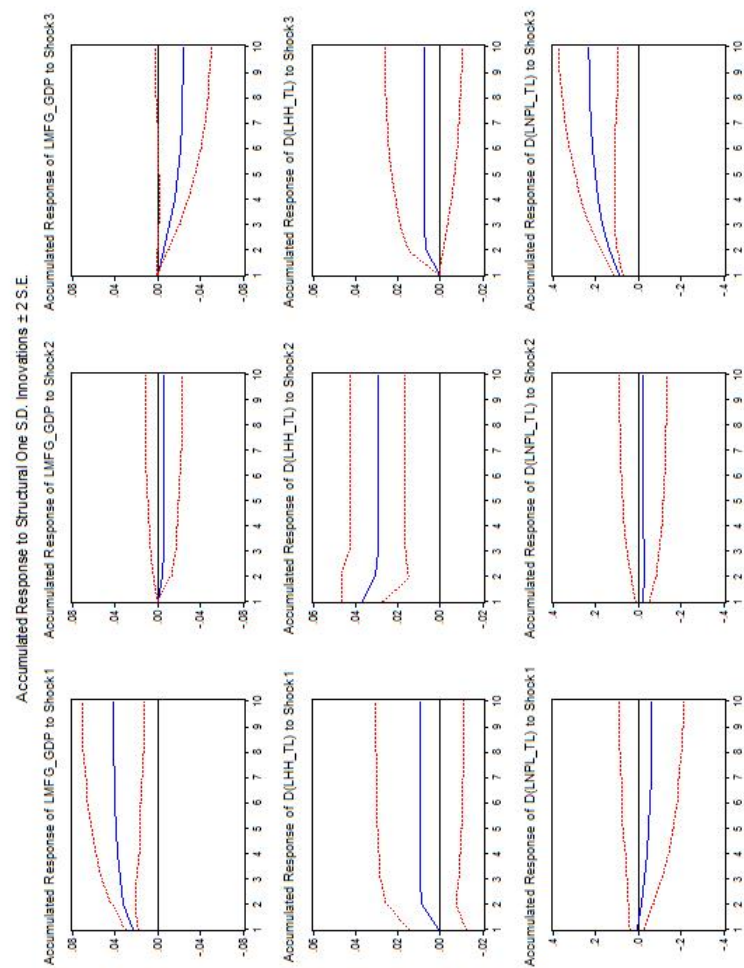


Figure B.31: Lithuania